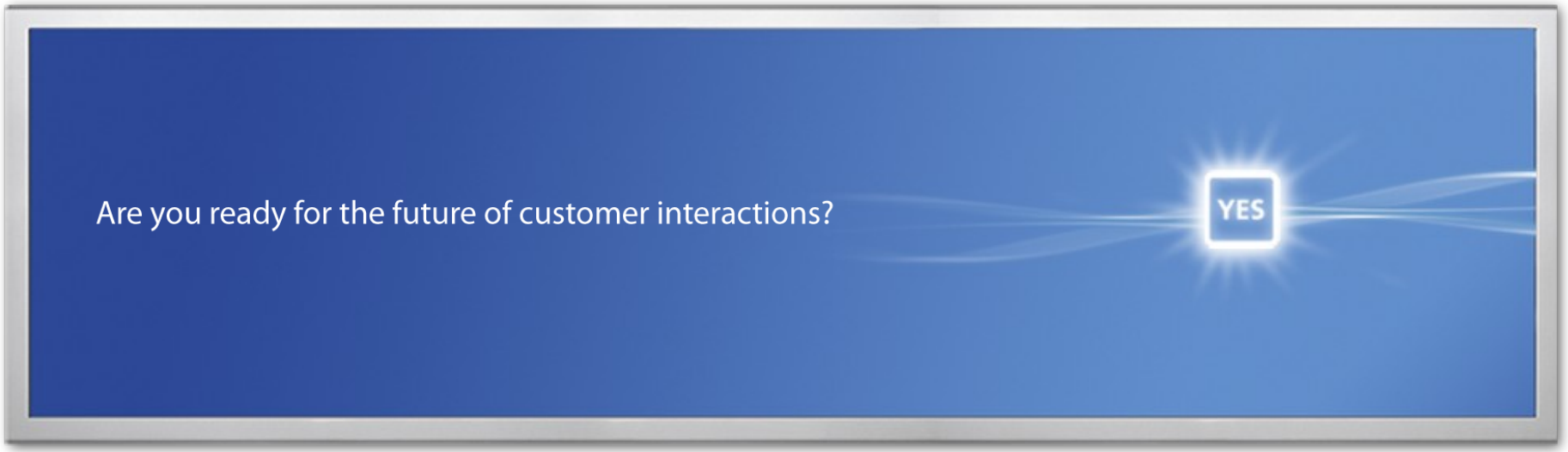


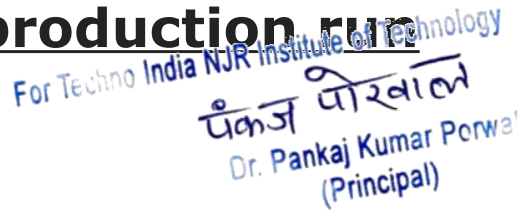
Production Part Approval Process (PPAP)

What is PPAP?

- **Production Part Approval Process**
- **Standard used to formally reduce risks prior to product or service release, in a team oriented manner using well established tools and techniques**
- **Initially developed by AIAG (Auto Industry Action Group) in 1993 with input from the Big 3 - Ford, Chrysler, and GM**
- **AIAG's 4th edition effective June 1, 2006 is the most recent version**
- **PPAP has now spread to many different industries beyond automotive**

Purpose of PPAP

- **Provide evidence that all customer engineering design record and specification requirements are properly understood by the organization**
- **To demonstrate that the manufacturing process has the potential to produce product that consistently meets all requirements during an actual production run at the quoted production rate**



PPAP manages change and ensures product conformance!

When is PPAP Required?

- **New part**
- **Engineering change(s)**
- **Tooling: transfer, replacement, refurbishment, or additional**
- **Correction of discrepancy**
- **Tooling inactive > one year**
- **Change to optional construction or material**
- **Sub-supplier or material source change**
- **Change in part processing**
- **Parts produced at a new or additional location**

PPAP is required with any significant change to product or process!

Benefits of PPAP Submissions

- **Helps to maintain design integrity**
- **Identifies issues early for resolution**
- **Reduces warranty charges and prevents cost of poor quality**
- **Assists with managing supplier changes**
- **Prevents use of unapproved and nonconforming parts**
- **Identifies suppliers that need more development**
- **Improves the overall quality of the product & customer satisfaction**

Production Run

- **PPAP data must be submitted from a *production* run using:**
  - **Production equipment and tooling**
  - **Production employees**
  - **Production rate**
  - **Production process**

All data reflects the actual production process to be used at start-up!

Run @ Rate

- **The purpose of a Run @ Rate is to verify the supplier's manufacturing process is capable of producing components that meet NCR's quality requirements, at quoted tooling capacity, for a specified period of time**
- **Verification of the Run @ Rate will be at the Supplier Quality Engineer's (SQE) discretion. The supplier will be notified of the need to perform a Run @ Rate as early in the process as possible.**
- **The number of components to be produced during the Run @ Rate should be sufficient to demonstrate process capability and will be predetermined by the SQE and the supplier.**
  - **Factors such as product complexity, shelf life, storage, cost and single shift vs. multiple shift operations will be taken into consideration**

Official PPAP Requirements

1. **Design Records**
2. **Authorized Engineering Change Documents**
3. **Customer Engineering Approval, if required**
4. **Design Failure Modes and Effects Analysis (DFMEA) *applied in special situations***
5. **Process Flow Diagram**
6. **Process Failure Modes and Effects Analysis (PFMEA)**
7. **Control Plan**
8. **Measurement Systems Analysis (MSA)**
9. **Dimensional Results**
10. **Records of Material / Performance Test Results**
11. **Initial Process Studies**
12. **Qualified Laboratory Documentation**
13. **Appearance Approval Report (AAR)**
14. **Sample Production Parts**
15. **Master Sample**
16. **Checking Aids**
17. **Customer-Specific Requirements**
18. **Part Submission Warrant (PSW)**

Now, let's take a closer look at NCR's requirements

NCR's PPAP Requirements

1. Design Records
2. **Authorized Engineering Change Documents**
3. **Customer Engineering Approval, if required**
4. Design Failure Modes and Effects Analysis (DFMEA) *applied in special situations*
5. **Process Flow Diagram**
6. **Process Failure Modes and Effects Analysis (PFMEA)**
7. **Control Plan**
8. **Measurement Systems Analysis (MSA)**
9. **Dimensional Results**
10. **Records of Material / Performance Test Results**
11. Initial Process Studies
12. **Qualified Laboratory Documentation**
13. **Appearance Approval Report (AAR)**
14. **Sample Production Parts**
15. Master Sample
16. Checking Aids
17. Customer-Specific Requirements
18. **Part Submission Warrant (PSW) – NCR calls this the "Production Warrant"**

Supplier shall submit these 12 items and retain a copy of records at appropriate locations

NCR's PPAP Requirements

1. **Design Records**
2. Authorized Engineering Change Documents
3. Customer Engineering Approval, if required
4. **Design Failure Modes and Effects Analysis (DFMEA) *applied in special situations***
5. Process Flow Diagram
6. Process Failure Modes and Effects Analysis (PFMEA)
7. Control Plan
8. Measurement Systems Analysis (MSA)
9. Dimensional Results
10. Records of Material / Performance Test Results
11. **Initial Process Studies**
12. Qualified Laboratory Documentation
13. Appearance Approval Report (AAR)
14. Sample Production Parts
15. **Master Sample**
16. **Checking Aids**
17. **Customer-Specific Requirements**
18. Part Submission Warrant (PSW) – NCR calls this the "Production Warrant"

Supplier shall retain these 6 items at appropriate locations, and make readily available upon request

PPAP Submission Levels

Level 1	Production Warrant and Appearance Approval Report (if applicable) submitted to NCR
Level 2	Production Warrant, product samples, and dimensional results submitted to NCR
Level 3	Production Warrant, product samples, and complete supporting data submitted to NCR
Level 4	Production Warrant and other requirements as defined by NCR
Level 5	Production Warrant, product samples and complete supporting data (a review will be conducted at the supplier's manufacturing location)

PPAP Submission Level Table

PPAP Levels for Submission & Retention

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

S = The supplier shall submit to NCR and retain a copy of records or documentation items at appropriate locations.

R = The supplier shall retain at appropriate locations and make ***readily*** available to NCR upon request.

* = The supplier shall retain at appropriate locations, and submit to NCR upon request. NCR will identify what is needed for submission.

PLEASE CONTACT YOUR SUPPLIER QUALITY ENGINEER WITH ANY QUESTIONS .

*** = Supplier shall retain at appropriate locations, and submit to NCR upon request. NCR will identify what is needed for submission.**

R = Supplier shall retain at appropriate locations and make *readily* available to NCR upon request

Definition of Risk

- **High Risk**
  - **Parts associated with multiple critical features, complex design, or high end technology that is not yet established in the general manufacturing environment**
  - **Supplier's quality system and/or quality performance is not to NCR satisfaction**
- **Medium Risk**
  - **Parts that have at least one critical feature**
- **Low Risk**
  - **Parts that have no critical features and can be manufactured by any manufacturer in the commodity category**
  - **Supplier's quality system and quality performance are acceptable**

Submission Level Requirements

- **New Parts**
  - Level 2 is required for Low Risk Parts
  - Level 3 is required for Medium and High Risk Parts

- **Part Changes**
  - Level 3 is required for Parts produced at a new or additional location
  - Supplier Quality Excellence will define the level required for all other changes

NCR reserves the right to redefine the submission level required

PPAP Status

- **Approved**
  - **The part meets all NCR requirements**
  - **Supplier is authorized to ship production quantities of the part**
- **Interim Approval**
  - **Permits shipment of part on a limited time or piece quantity basis**
- **Rejected**
  - **The part does not meet NCR requirements, based on the production lot from which it was taken and/or accompanying documentation**

Production quantities may not be shipped before NCR Approval

Electronic Submission Requirements

- NCR requires that all PPAPs be submitted electronically
- Use of paper submission must have prior approval by the SQE
- Submission must be received *on or prior to* the **PPAP due date**
- **Review and Approval Process:**
  - NCR will attempt to review and provide feedback within 2 business days

NCR requires all submissions to be electronic

NCR PPAP Playbook

- **What is the NCR PPAP Playbook?**
  - **An Excel spreadsheet containing templates of the documents suppliers are required to submit to NCR**

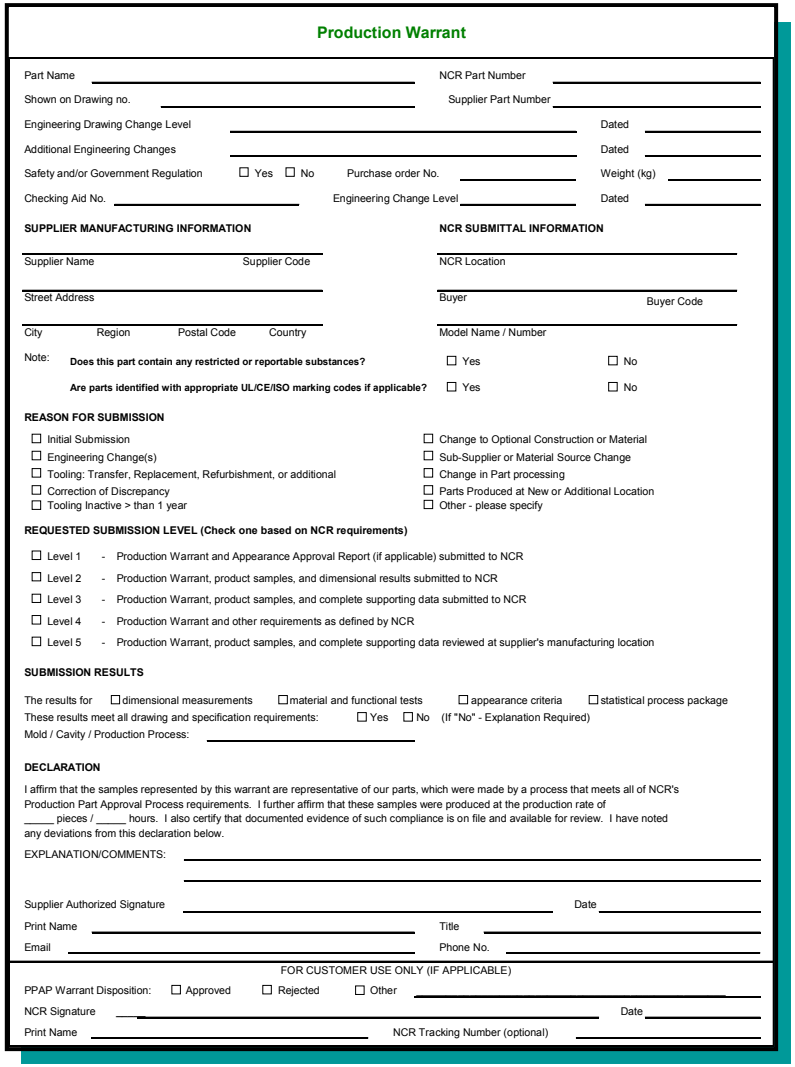
- **Why use the PPAP Playbook?**
  - **Simplifies the process for suppliers by serving as a "checklist" of what needs to be submitted to NCR**
  - **Reduces the number of files to manage**
  - **Enables the SQE to quickly see if anything is missing**

Show PPAP Playbook

PRODUCTION WARRANT

For Techno India NJR Institute of Technology
पंकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

Production Warrant



Production Warrant

Part Name _____ NCR Part Number _____

Shown on Drawing no. _____ Supplier 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. _____ Engineering Change Level _____ Dated _____

SUPPLIER MANUFACTURING INFORMATION

Supplier Name _____ Supplier Code _____

Street Address _____

City _____ Region _____ Postal Code _____ Country _____

NCR SUBMITTAL INFORMATION

NCR Location _____

Buyer _____ Buyer Code _____

Model Name / Number _____

Note: **Does this part contain any restricted or reportable substances?** ☐ Yes ☐ No

Are parts identified with appropriate UL/CE/ISO marking codes if applicable? ☐ Yes ☐ No

REASON FOR SUBMISSION

☐ Initial Submission
☐ Engineering Change(s)
☐ Tooling: Transfer, Replacement, Refurbishment, or additional
☐ Correction of Discrepancy
☐ Tooling Inactive > than 1 year
☐ Change to Optional Construction or Material
☐ Sub-Supplier or Material Source Change
☐ Change in Part processing
☐ Parts Produced at New or Additional Location
☐ Other - please specify

REQUESTED SUBMISSION LEVEL (Check one based on NCR requirements)

☐ Level 1 - Production Warrant and Appearance Approval Report (if applicable) submitted to NCR
☐ Level 2 - Production Warrant, product samples, and dimensional results submitted to NCR
☐ Level 3 - Production Warrant, product samples, and complete supporting data submitted to NCR
☐ Level 4 - Production Warrant and other requirements as defined by NCR
☐ Level 5 - Production Warrant, product samples, and complete supporting data reviewed at supplier's manufacturing location

SUBMISSION RESULTS

The results for ☐dimensional measurements ☐material and functional tests ☐appearance criteria ☐statistical process package
These results meet all drawing and specification 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 of NCR's Production Part Approval Process requirements. I further affirm that these samples were produced at the production rate of _____ pieces / _____ 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: _____

Supplier Authorized Signature _____ Date _____

Print Name _____ Title _____

Email _____ Phone No. _____

FOR CUSTOMER USE ONLY (IF APPLICABLE)

PPAP Warrant Disposition: ☐ Approved ☐ Rejected ☐ Other _____

NCR Signature _____ Date _____

Print Name _____ NCR Tracking Number (optional) _____

What is It?

- Document required for all newly tooled or revised products in which the supplier confirms that inspections and tests on production parts show conformance to NCR requirements

Objective or Purpose

Used to :

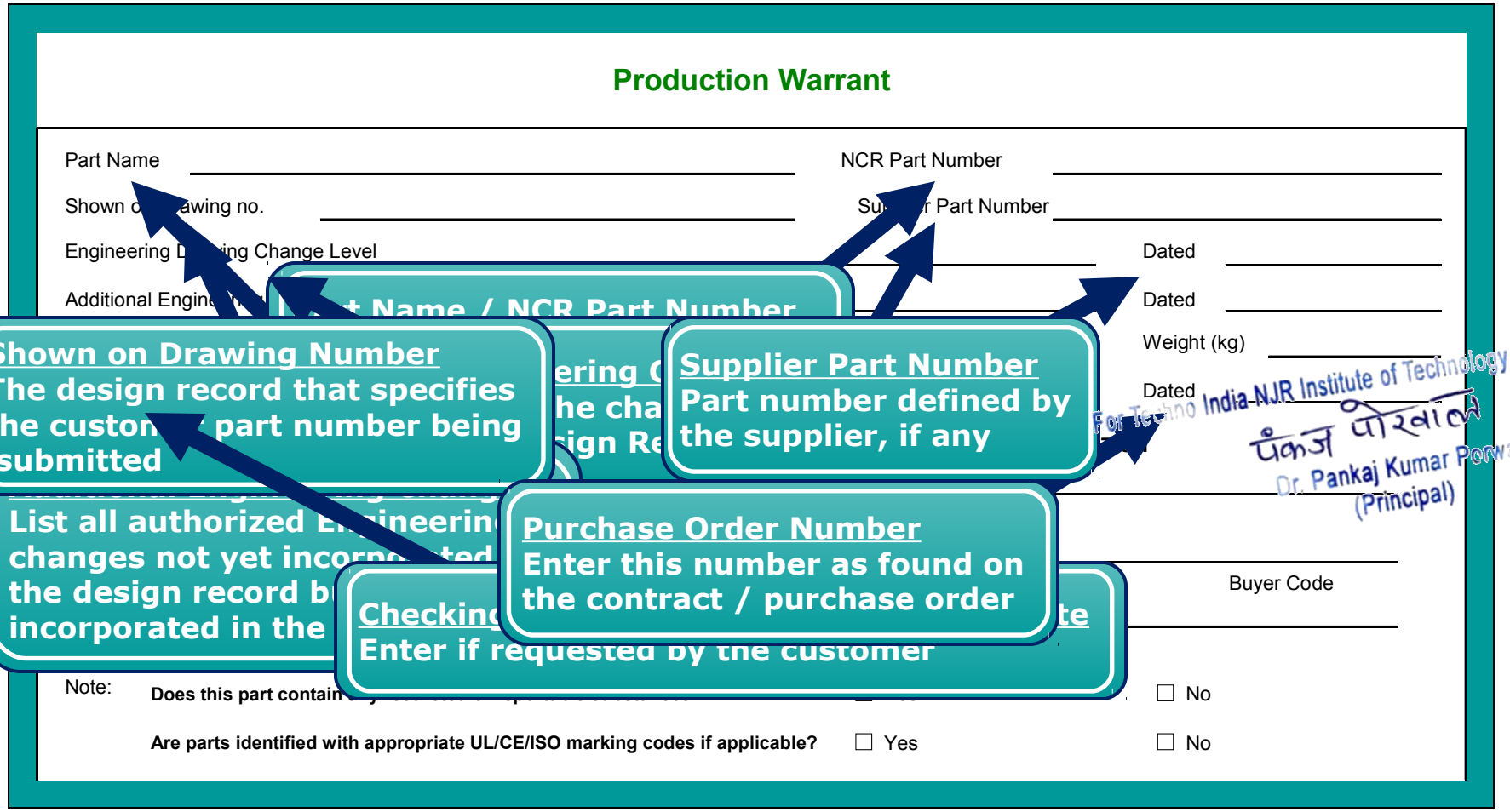
- document part approval
- provide key information
- declare that the parts meet specification

When to Use It

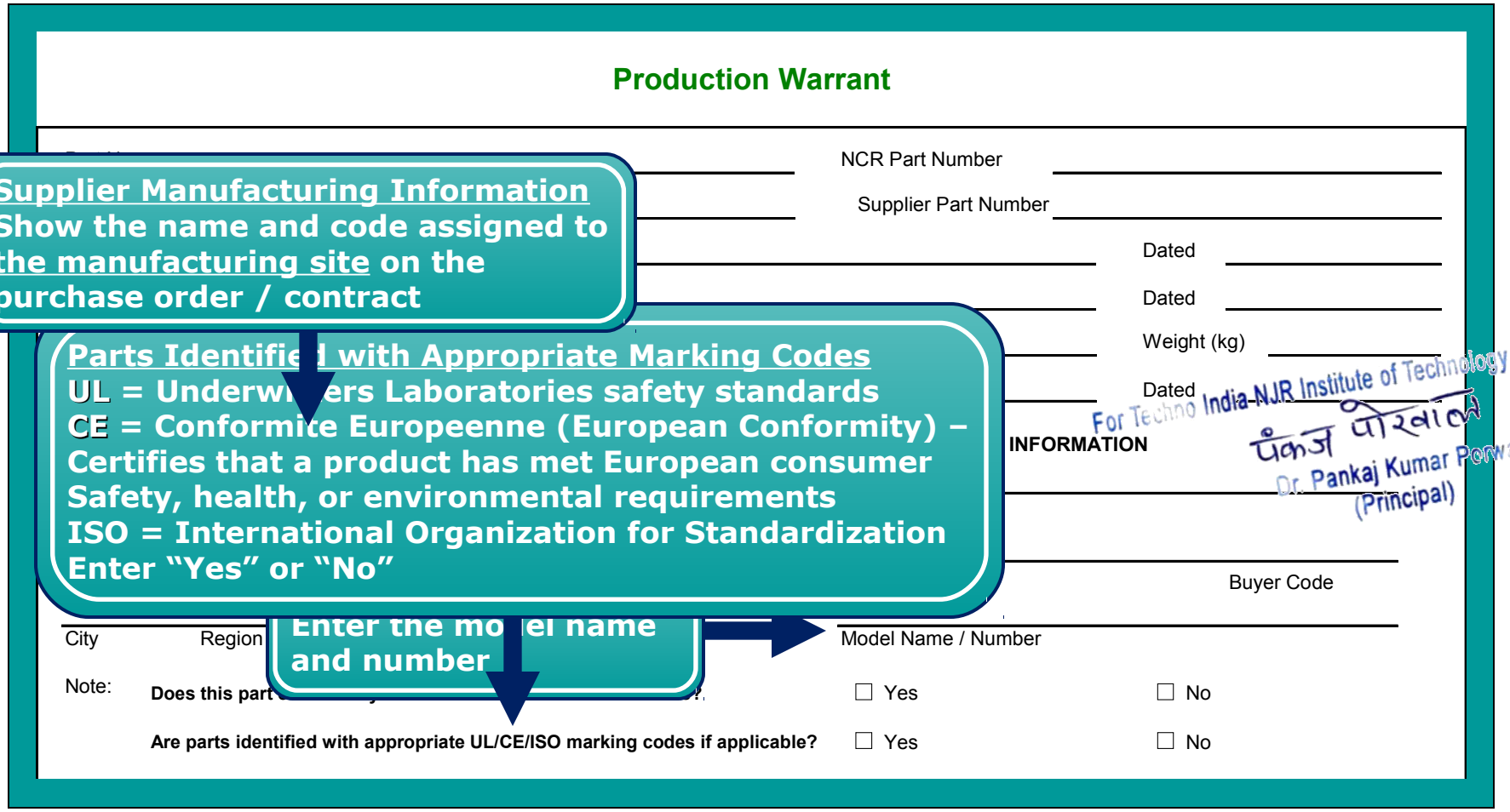
- Prior to shipping production parts

Now, let's take a closer look

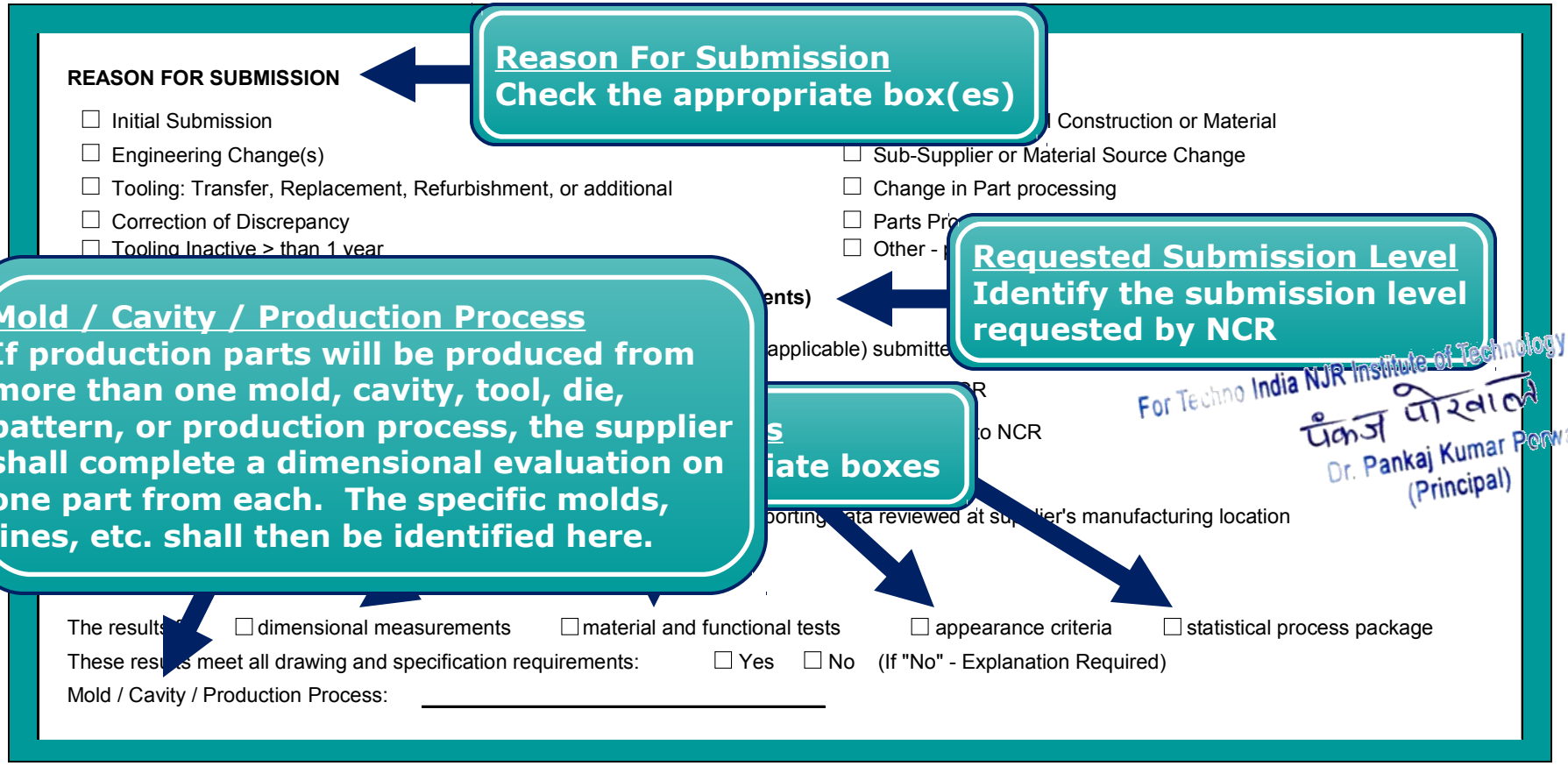
Production Warrant



Production Warrant



Production Warrant



Production Warrant

Explanation / Comments
Provide any explanatory c

Supplier Authorized Sign
A responsible supplier of
that the results show conformance to all NCR
requirements and that all required documentation
is available, shall approve the declaration

Declaration
Affirmation that the samples represented by the warrant are representative and were made by a process that meets NCR's PPAP requirements

For NCR Use Only
e completed by appropriate
Supplier Quality Engineer

NCR Signature
Signed by NCR Supplier Quality Engineer

made by a process that meets all of NCR's
duced at the production rate of
n file and available for review. I have noted

Date

Title

Phone No.

For Techno India NJR Institute of Technology
Dr. Pankaj Kumar Pa
(Principal)

FOR NCR USE ONLY

PPAP W ant Disposition: ☐ Approved ☐ Rejected ☐ Other

NCR Signature

Date

Print Name

NCR Tracking Number (optional)

The approved Production Warrant officially warrants the parts ready for production

Production Warrant

Reviewers Checklist

- ✓ **Must be completely filled out**
- ✓ **Must be signed by the supplier**
- ✓ **P/N must match the PO**
- ✓ **Submitted at the correct revision level**
- ✓ **Submitted at the correct submission level**
- ✓ **Specify the reason for submission**

AUTHORIZED ENGINEERING CHANGE DOCUMENTS

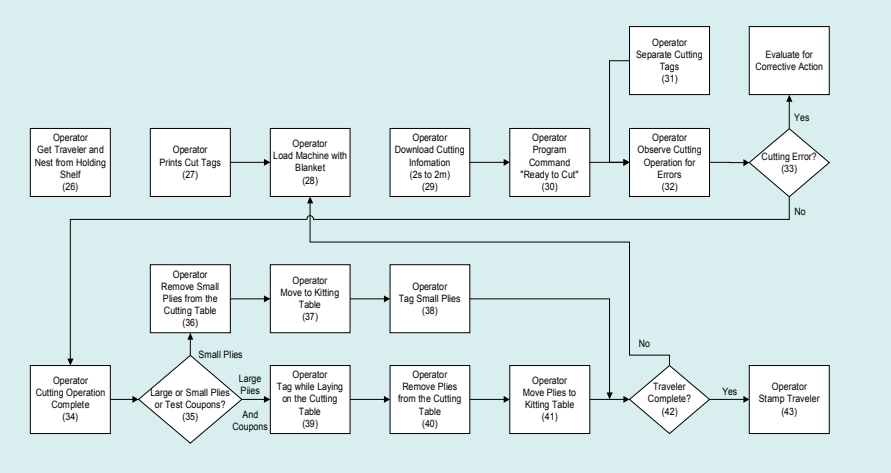
Authorized Engineering Change Documents

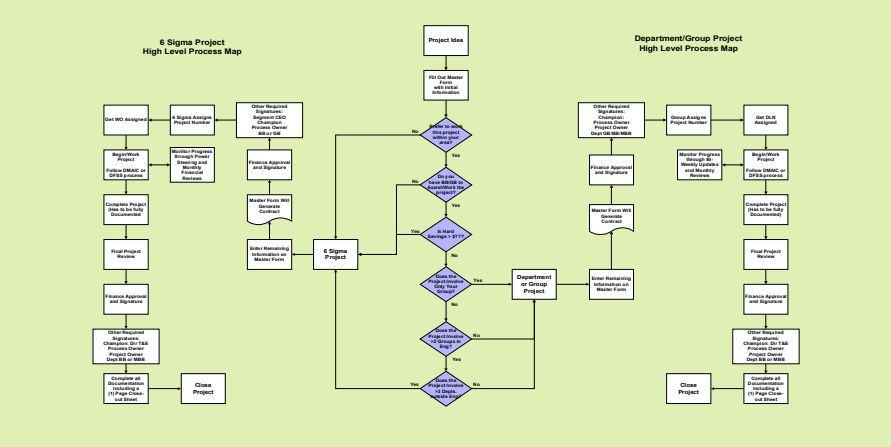
The supplier shall provide authorized change documents for those changes not yet recorded in the design record, but incorporated in the product, part or tooling, such as:

- **ECNs *(must be approved, not pending)***
- **Specifications**
- **Feasibility studies**
- **Supplier change requests**
- **Sub-assembly drawings**
- **Life or reliability testing requirements**

PROCESS FLOW DIAGRAM

Process Flow Diagram





What is It?

- A visual diagram of the entire process from **receiving through shipping,** including outside processes and services

Objective or Purpose

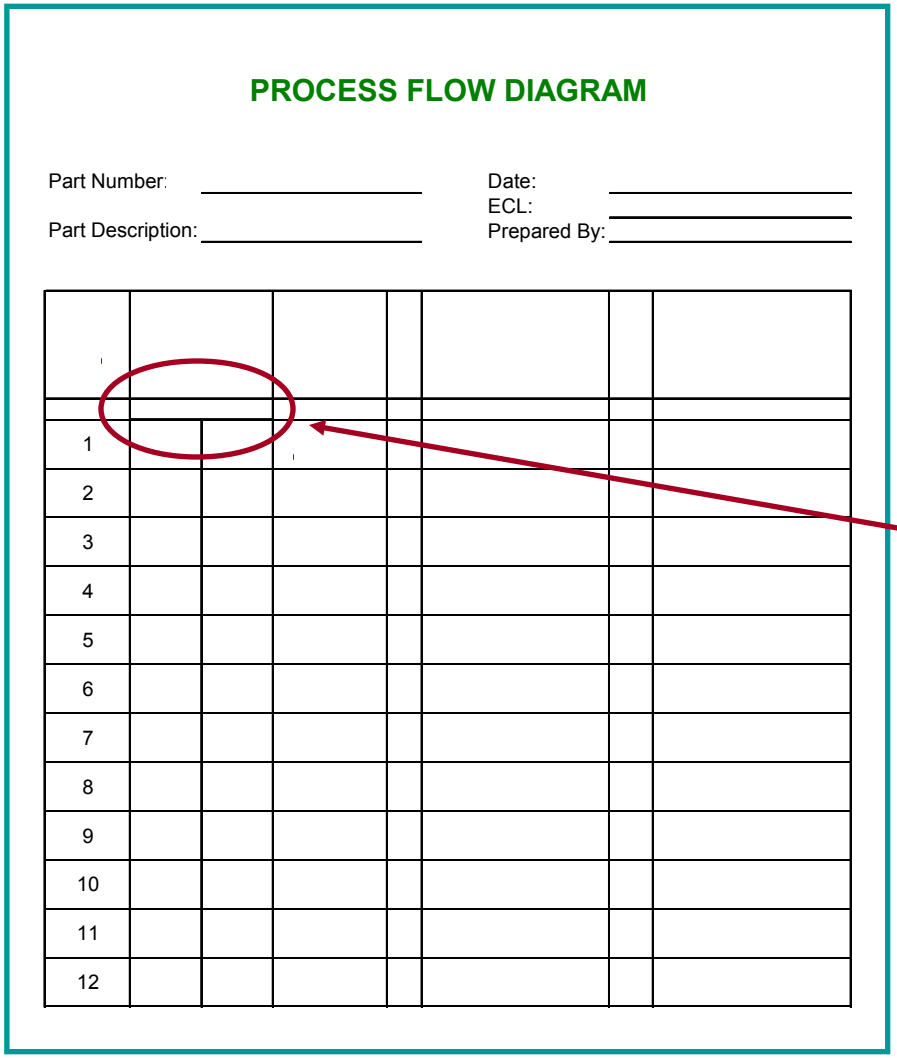
To help people "see" the real process. Process maps can be used to understand the following characteristics of a process:

- Set-by-step process linkage
- Offline activities (measurement, inspection, handling)
- Rework, scrap

When to Use It

- To understand how a process is done
- Prior to completing the PFMEA

Process Flow Diagrams



PROCESS FLOW DIAGRAM

Part Number: _____ Date: _____

ECL: _____

Part Description: _____ Prepared By: _____

1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

The process flow diagram utilizes these symbols to clearly identify each step in the process

Process Flow Diagram - Example

	PROCESS FLOW DIAGRAM	F/QA/05/0
Part No.	Customer Name : ***NCR***	Doc. No. :
Part Name : : ***Shaft Pressure Paddle***	Page : ***1 of 1***	Rev. No. / Date : ***O / 10.08.09***

Incoming Inspection **05**

CNC Sliding Machining **10**

Deburring & Cleaning **15**

Final Isnpection **20**

**RM receiving Insp. report

Patrol Insp. report

Final Inspection register

Despatch **70**

Pre shipment audit **60**

Oiling, Packing & Preservation **50**

Layout Inspection **40**

Pre delivery Inspection **30**

Pre shipment audit report

Layout Inspection Report

Self Inspection Report

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पंकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

**

Inspection as per RIQP

If Rejected

Not ok , Rejected

Inspection as per Opertion layout

If rework possible

Rework

100% Re-inspection

Not ok , Rejected

Return to supplier

Note :
Tags to be provided for OK, Rework, Inspection & Rejection

Not ok

Scrap

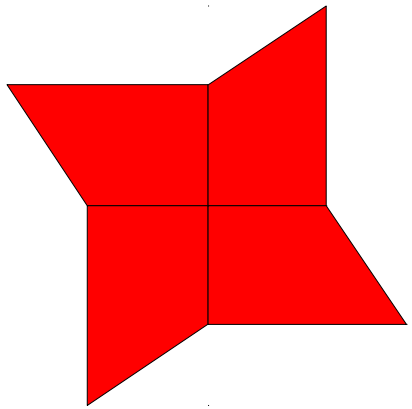
Ok

Next operation

- MOVEMENT - SUPPLIER END OPERATION	- PATROL INSPECTION - PROCESS	- STORAGE - INSPECTION	**PREPARED BY & DATE**	**APPROVED BY & DATE**

Star Exercise

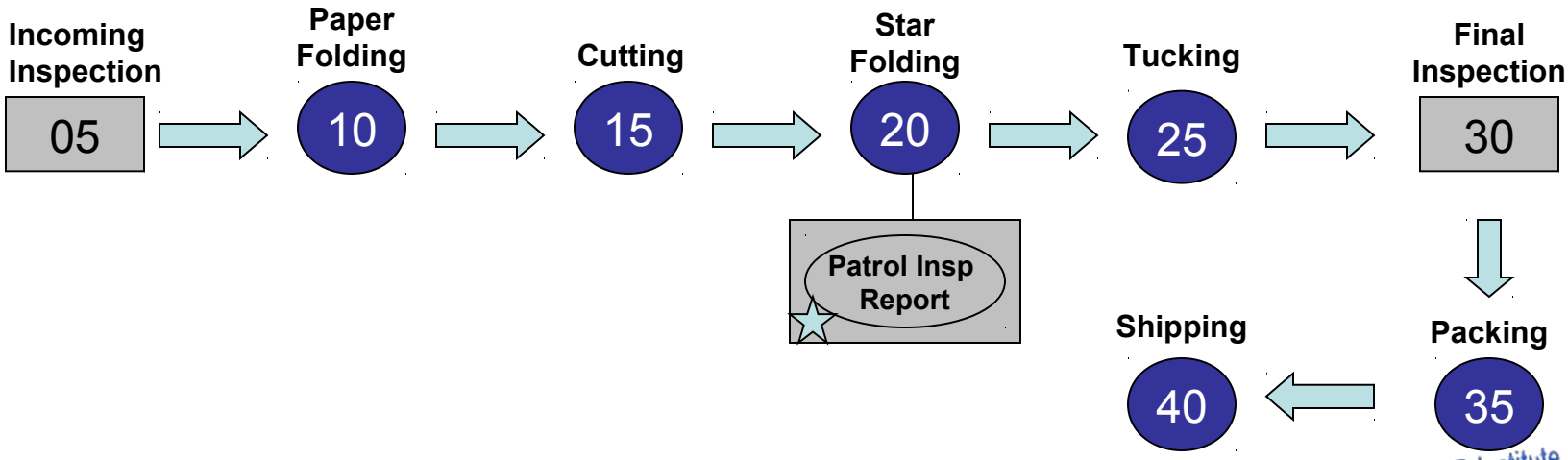
- **Divide into teams**
- **Distribute supplies**
  - **Paper for Stars**
  - **Instructions for making Stars**
  - **Scissors**

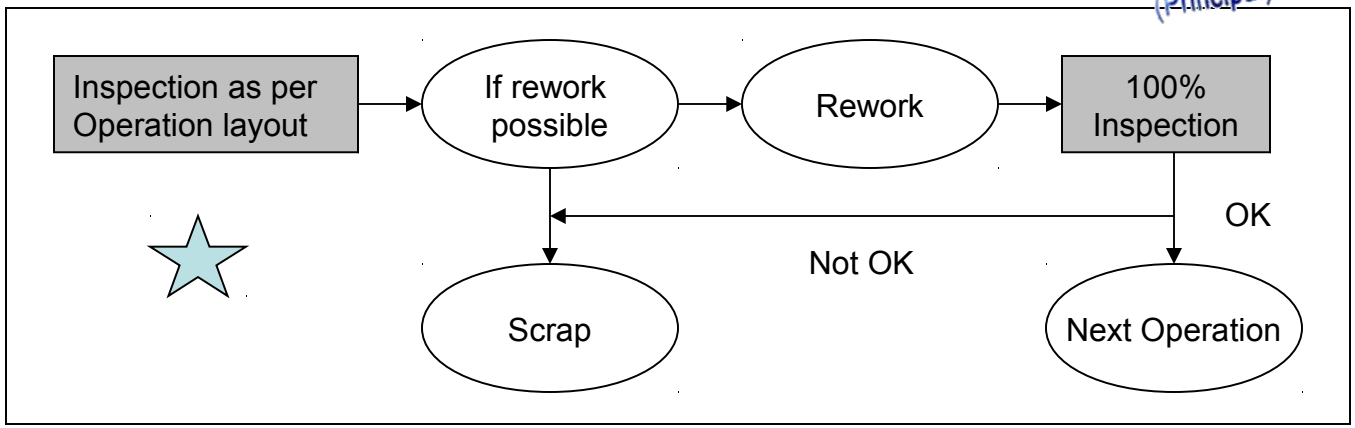


- **Using the instructions handed out in class, make 10 Shuriken Stars**
- **This exercise will prepare your team to complete future exercises**

45 Minutes

Process Flow Diagram – Star Exercise

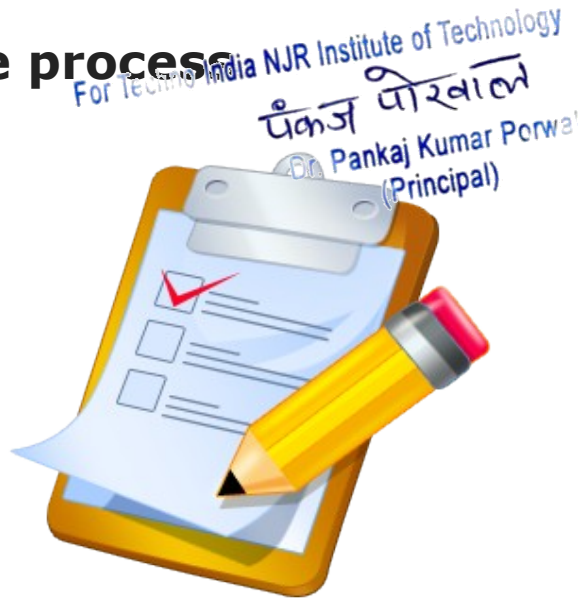




Process Flow Diagrams

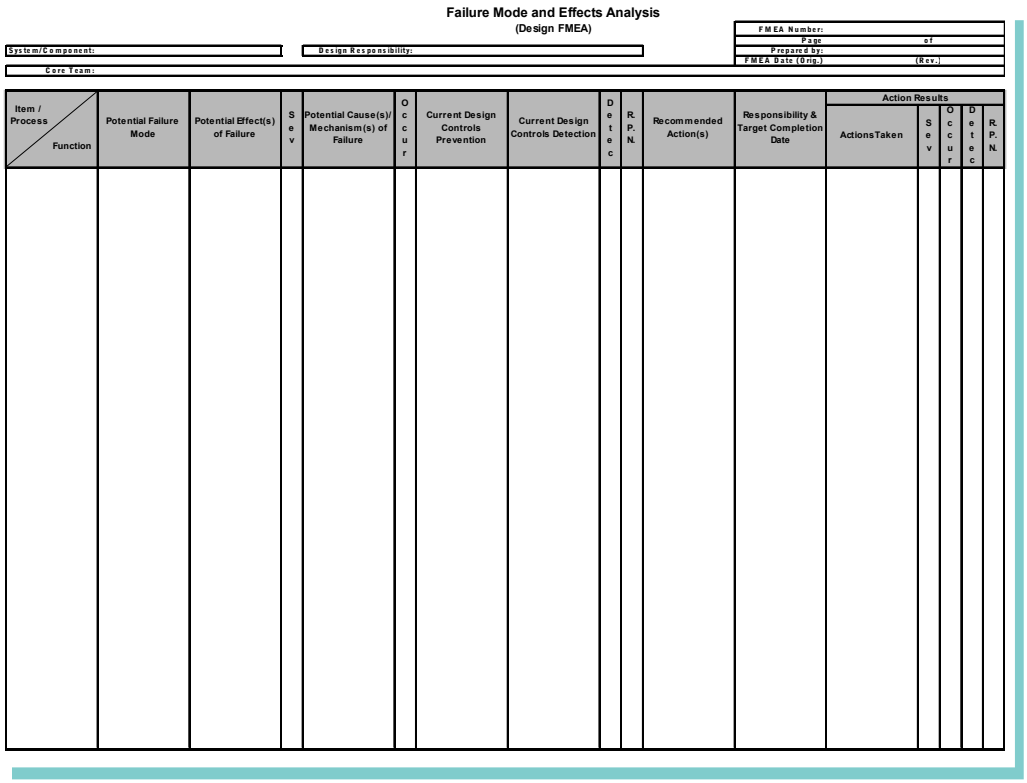
Reviewers Checklist

- ✓ **Process Flow must identify each step in the process**
- ✓ **Should include abnormal handling processes**
  - **Scrap**
  - **Rework**
- ✓ **Process Flow must include all phases of the process**
  - **Receiving of raw material**
  - **Part manufacturing**
  - **Offline inspections and checks**
  - **Assembly**
  - **Shipping**



PROCESS FMEA

Process FMEA (PFMEA)



Failure Mode and Effects Analysis
(Design FMEA)

System/Component: | Design Responsibility: | FMEA Number: | Page of | Prepared by: | FMEA Date (Orig.) (Rev.) | Core Team:

Item / Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls Prevention	Current Design Controls Detection	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occur	Detec	R.P.N.

IMPORTANT!

The PFMEA should be completed using a *cross-functional* team!

What is It?

- A tool used to identify and prioritize risk areas and their mitigation plans.

Objective or Purpose

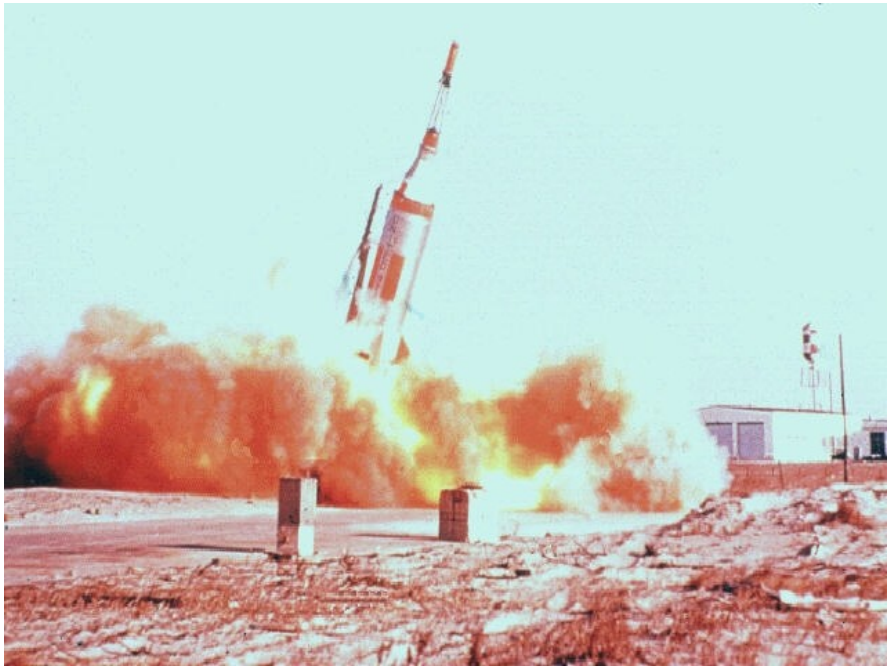
- Identifies potential failure modes, causes, and effects. Inputs come from the process flow diagram.
- Identifies key inputs which positively or negatively affect quality, reliability and safety of a product or process.

When to Use It

- After completion of the process flow diagram.
- Prior to tooling for production

FMEA Origin

- **Created by NASA following Apollo 1 mission failure**
- **Allows us to take a proactive approach to what can go wrong in a process and manage our risks better**



Process FMEA (PFMEA)

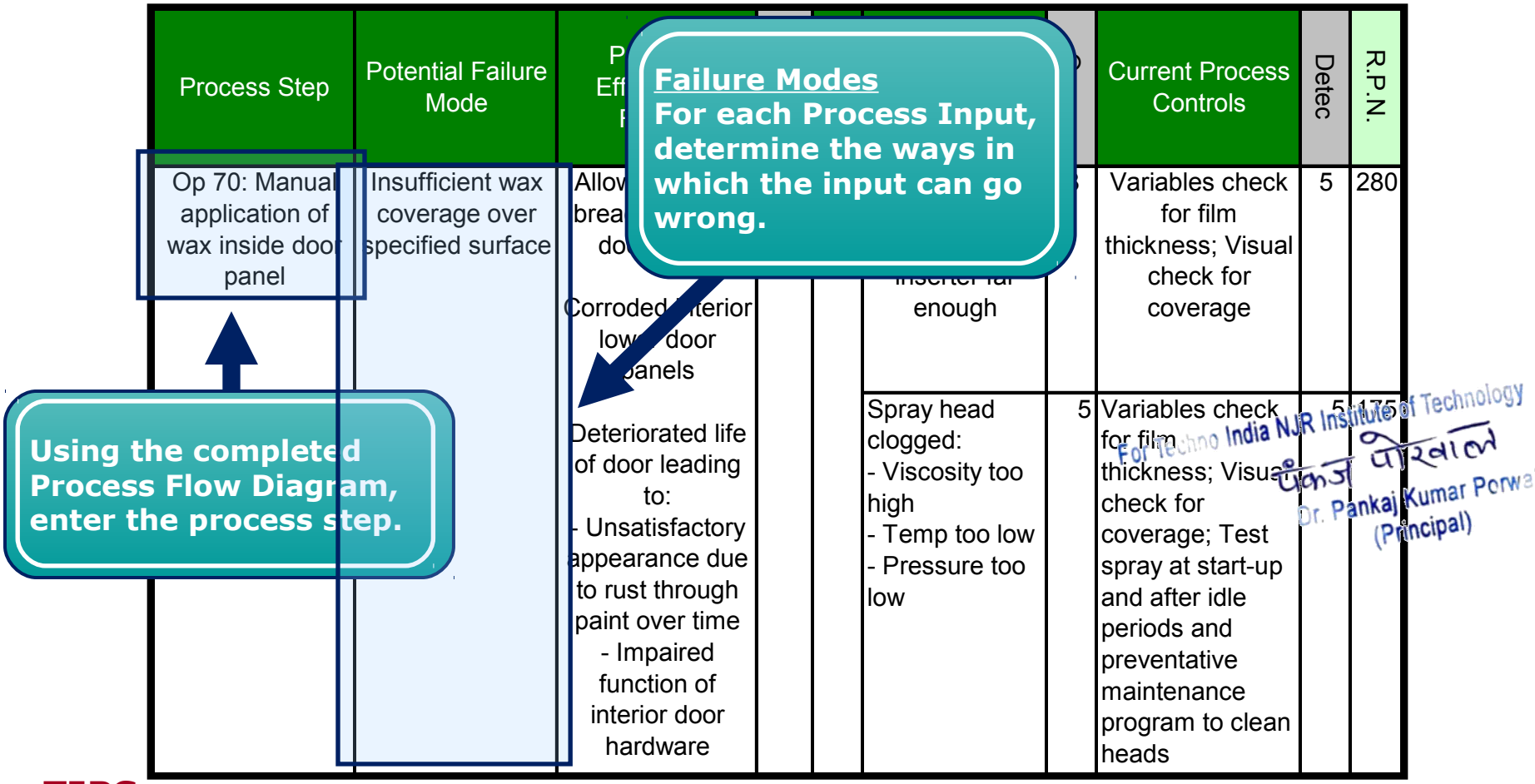
POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(PROCESS FMEA)

Print # _____ Rev. _____ FMEA Number _____
Item: _____ Process Responsibility: _____ Prepared by: _____
Model Year(s)/Vehicle(s) _____ Key Date _____ Date (Orig.) _____
Team: _____ Date (Rev.) _____

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.	Recommended Actions	Responsibility & Target Date	Action Results				
												Actions Taken	Sev	Occ	Det	R.P.N.

This is included in the PPAP Playbook!

PFMEA - Step 1



Process Step	Potential Failure Mode	P Eff					Current Process Controls	Detec	R.P.N.
Op 70: Manual application of wax inside door panel	Insufficient wax coverage over specified surface	Allov brea do Corroded terior low door panels Deteriorated life of door leading to: - Unsatisfactory appearance due to rust through paint over time - Impaired function of interior door hardware				enough	Variables check for film thickness; Visual check for coverage	5	280
					5	Spray head clogged: - Viscosity too high - Temp too low - Pressure too low	5 Variables check for film thickness; Visual check for coverage; Test spray at start-up and after idle periods and preventative maintenance program to clean heads	5	175

Failure Modes
For each Process Input, determine the ways in which the input can go wrong.

Using the completed Process Flow Diagram, enter the process step.

TIPS

- **There should be at least one failure mode for each input.**

PFMEA - Step 2

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.
Op 70: Manual application of wax inside door panel	Insufficient wax coverage over specified surface	Allows integrity breach of inner door panel Corroded interior lower door panels Deteriorated life of door leading to: - Unsatisfactory appearance due to rust through paint over time - Impaired function of interior door hardware	7		Manually inserted spray h… in…	8	Variables check for film	5	280
					Spra… clog… - Vis… high - Temp too low - Pressure too low		coverage; Test spray at start-up and after idle periods and preventative maintenance program to clean heads		175

Potential Failure Effects
For each Failure Mode, determine what effect the specific failure could have on the process output.

TIPS

- **There should be at least one failure effect for each failure mode.**
- **Effects should be specific, clear, and leave no doubt to the uninformed reviewer.**

PFMEA - Step 3

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.
Op 70: Manual application of wax inside door	Insufficient wax coverage over specified surface	Allows integrity breach of inner door panel rior life ing to: - Unsatisfactory appearance due to rust through paint over time - Impaired function of interior door hardware	7		Manually inserted spray head not inserted far enough	8	Variables check for film thickness; Visual check for coverage	5	280
					Spray head clogged: - Viscosity too high - Temp too low - Pressure too low	5	Variables check for film thickness; Visual check for coverage; Test spray at start-up and after idle periods and preventative maintenance program to clean heads	5	175

Potential Causes
For each Failure Mode, determine the possible cause of the failure.

TIPS

- **There should be at least one potential cause for each failure mode.**

PFMEA - Step 4

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.
Op 70: Manual application of wax inside door panel	Insufficient wax coverage over specified surfa	Allows integrity	7		Manually ed spray not er far gh	8	Variables check for film thickness; Visual check for coverage	5	280
		- Unsatisfactory appearance due			ad ty too high - Temp too low - Pressure too	5	Variables check for film thickness; Visual check for coverage; Test spray at start-up	5	175

Current Controls
For each potential cause, list the current method used for preventing or detecting failure.

TIPS

- **This step in the FMEA begins to identify initial shortcomings or gaps in the current control plan.**
- **If a procedure exists, enter the document number.**
- **If no current control exists, list as "none."**

PFMEA - Step 5

Assign Severity, Occurrence, and Detection ratings

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.
Op 70: Ma applicatio wax inside panel		of inner panel Corroded interior lower door panels	7		Manually	8	Variables check for film ss; Visual erage	5	280
		appearance due to rust through paint over time - Impaired function of interior door hardware			ay head ged: emp too low - Pressure too low	5	Variables check for film thickness; Visual check for coverage; Test spray at start-up and after idle periods and preventative maintenance program to clean heads	5	125

Assign Severity (How serious is the effect if it fails?)

Assign Occurrence (How likely is the cause to occur?)

Assign Detection (How easily can the cause or failure mode be detected?)

Severity, Occurrence and Detection rating details on next slide

PFMEA - Definition of Terms

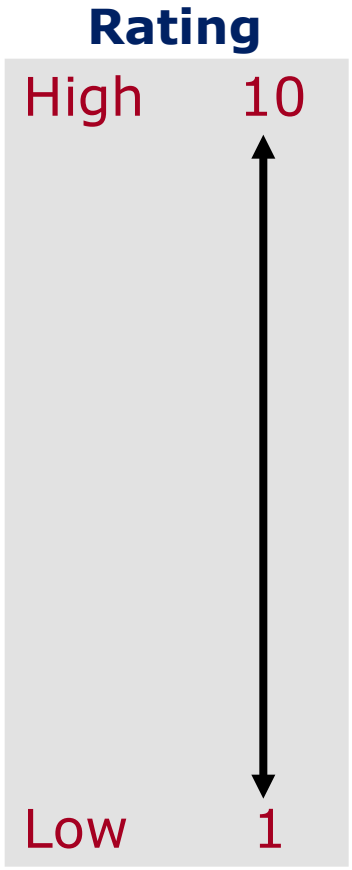
Severity (of Effect) - severity of the effect on the Customer and other stakeholders (Higher Value = Higher Severity)

Occurrence (of Cause) - frequency with which a given Cause occurs and creates Failure Mode. (Higher Value = Higher Probability of Occurrence)

Detection (Capability of Current Controls) - ability of current control scheme to detect the cause before creating the failure mode and/or the failure mode before suffering the effect (Higher Value = Lower Ability to Detect)

Caution: Notice the scale difference for Detection!

An Example of Rating Definitions



Severity	Occurrence	Detection*
Hazardous without warning	Very high and almost inevitable	Cannot detect or detection with very low probability
Loss of primary function	High repeated failures	Remote or low chance of detection
Loss of secondary function	Moderate failures	Low detection probability
Minor defect	Occasional failures	Moderate detection probability
No effect	Failure unlikely	Almost certain detection

If No Controls Exist, Detection = 10

Create a rating system that makes sense for the defects you are trying to prevent.

PFMEA - Step 6

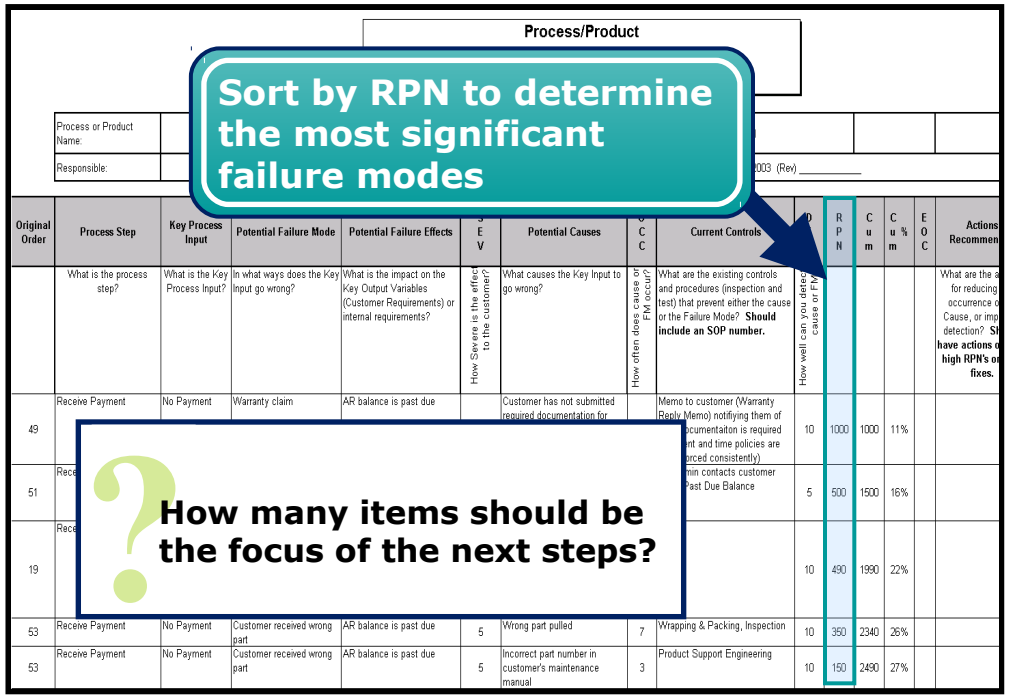
Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.
Op 70: Manual application of wax inside door panel	Insufficient wax coverage over	Allows integrity breach of inner	7		Manually inserted spray	8	Variables check for film Visual or e	5	280
		Deteriorated life of door leading			clogged: - Viscosity too		for film thickness; Visual		

Calculate the Risk Priority Number
RPN = Severity x Occurrence x Detection

TIPS

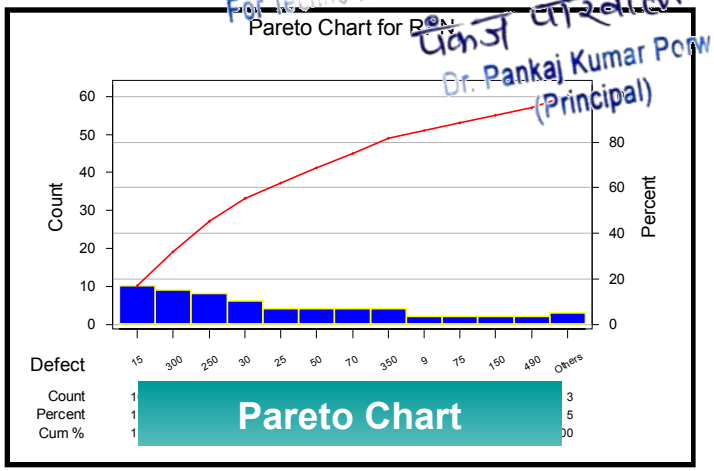
- **The RPN is used to prioritize the most critical risks identified in the first half of the FMEA.**
- **High RPNs (125 or above) are flags to take effort to reduce the calculated risk.**
- **Regardless of RPN, *high Severity* scores (9 or 10) should be given special attention.**

Analyzing the PFMEA



Original Order	Process Step	Key Process Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Cum	Cum%	EOC	Actions Recommen
	What is the process step?	What is the Key Process Input?	In what ways does the Key Input go wrong?	What is the impact on the Key Output Variables (Customer Requirements) or internal requirements?	How Severe is the effect to the customer?	What causes the Key Input to go wrong?	How often does cause or FM occur?	What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode? **Should include an SOP number.**	How well can you detect cause or FM					What are the a for reducing occurrence Cause, or imp detection? **have actions high RPN's o fixes.**
49	Receive Payment	No Payment	Warranty claim	AR balance is past due		Customer has not submitted required documentation for		Memo to customer (Warranty Reply Memo) notifiying them of ocumentaiton is required nt and time policies are rced consistently)	10	1000	1000	11%		
51	Rece							min contacts customer Past Due Balance	5	500	1500	16%		
19	Rece								10	490	1990	22%		
53	Receive Payment	No Payment	Customer received wrong part	AR balance is past due	5	Wrong part pulled	7	Wrapping & Packing, Inspection	10	350	2340	26%		
53	Receive Payment	No Payment	Customer received wrong part	AR balance is past due	5	Incorrect part number in customer's maintenance manual	3	Product Support Engineering	10	150	2490	27%		

- Once the RPN Numbers are determined, they can be used to prioritize the most significant failure modes.
- Sort the FMEA by the RPN numbers. Graphical and statistical tools can help the team select a "cut-off" RPN for the next steps.



RPN Thresholds

- When using an RPN threshold, DO NOT forget to address high *Severity* scores

PFMEA – Remediation Guidelines

Severity – can only be improved by a design change to the product or process

Occurrence – can only be reduced by a change which removes or controls a cause. Examples are redundancy, substituting a more reliable component or function or mistake-proofing.

Detection – can be reduced by improving detection. Examples are mistake-proofing, simplification and statistically sound monitoring.

In general, reducing the Occurrence is preferable to improving the Detection

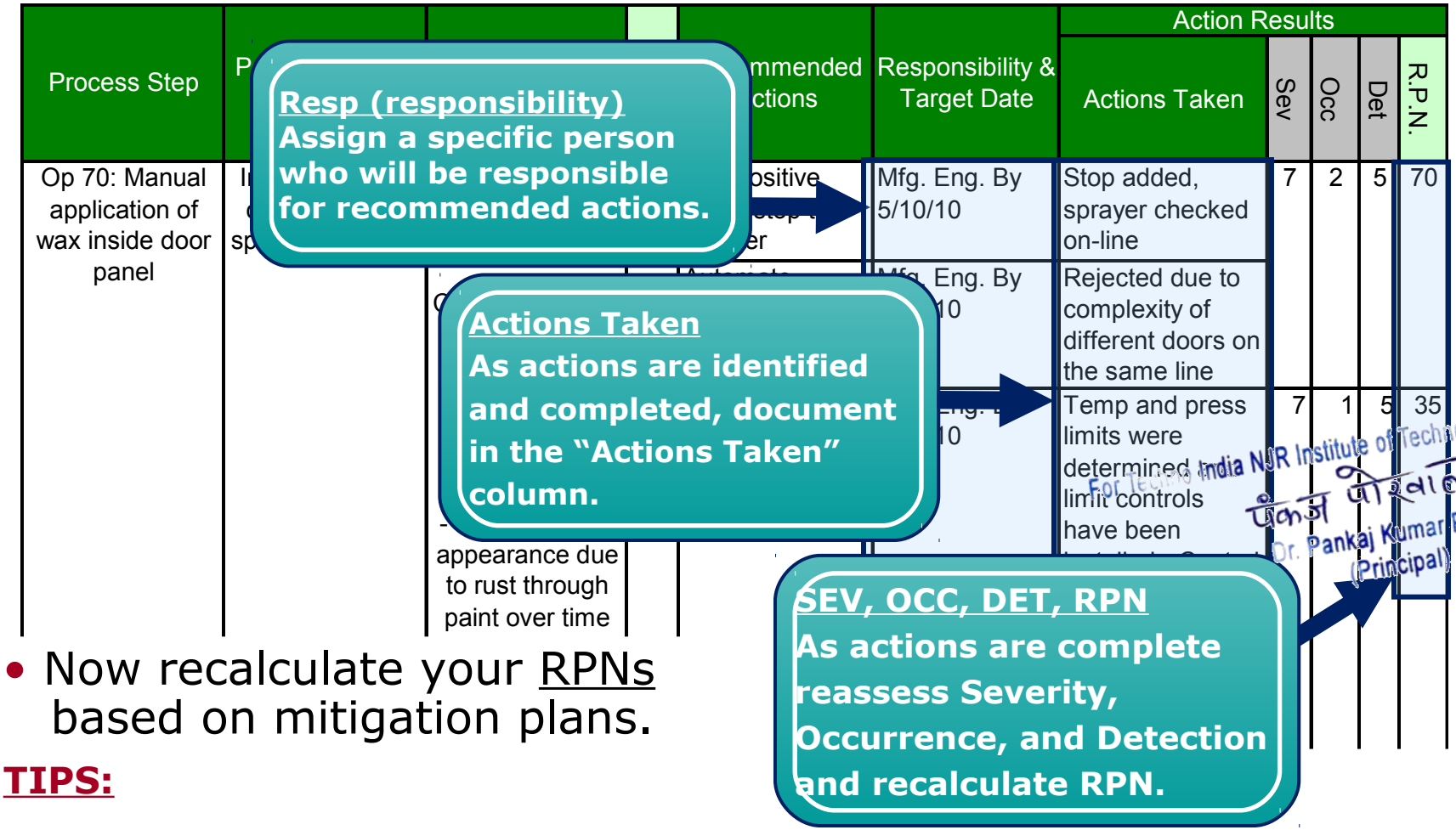
FMEA – Step 7

- **Determine <u>Actions Recommended</u> to reduce High RPNs**

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	R.P.N.	Recommended Actions	Responsibility & Target Date	Action Results				
						Actions Taken	Sev	Occ	Det	R.P.N.
Op 70: Manual application of wax inside door	Insufficient wax coverage over specified surface	Allows integrity breach of inner door panel	280	Add positive depth stop to sprayer	Mfg. Eng. By 5/10/10	Stop added, sprayer checked on-line	7	2	5	70
				Automate spraying	Mfg. Eng. By 5/25/10	Rejected due to complexity of different doors on the same line				
		ated life leading to: - Unsatisfactory appearance due to rust through paint over time - Impaired function of interior door hardware	175	Use DOE on viscosity vs. temp vs. pressure	Mfg. Eng. By 5/31/10	Temp and press limits were determined and limit controls have been installed - Control charts show process is in control Cpk = 1.85	7	1	5	35

For the high RPN numbers, determine the recommended actions.

FMEA – Steps 8 and 9



Process Step	P		mmended ctions	Responsibility & Target Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
Op 70: Manual application of wax inside door panel	I… sp…		…ositive …er	Mfg. Eng. By 5/10/10	Stop added, sprayer checked on-line	7	2	5	70
				…Eng. By …10	Rejected due to complexity of different doors on the same line				
				…Eng. … …10	Temp and press limits were determined and limit controls have been	7	1	5	35
		appearance due to rust through paint over time							

Resp (responsibility)
Assign a specific person who will be responsible for recommended actions.

Actions Taken
As actions are identified and completed, document in the "Actions Taken" column.

SEV, OCC, DET, RPN
As actions are complete reassess Severity, Occurrence, and Detection and recalculate RPN.

- Now recalculate your RPNs based on mitigation plans.

TIPS:

Continue updating the actions taken and resulting RPNs until all risks are at an acceptable level (below 125).

Summary Steps To Complete a FMEA

1. For each Process Input, determine the ways in which the Process Step can go wrong (these are Failure Modes).
2. For each Failure Mode associated with the inputs, determine Effects on the outputs.
3. Identify potential Causes of each Failure Mode.
4. List the Current Controls for each Cause.
5. Assign Severity, Occurrence and Detection ratings after creating a ratings key appropriate for your project.
6. Calculate RPN.
7. Determine Recommended Actions to reduce High RPNs.
8. Take appropriate Actions and Document.
9. Recalculate RPNs.
10. Revisit steps 7 and 8 until all the significant RPNs have been addressed.

PFMEA Exercise

Instructions

- **Open the PPAP Training Templates.xls file, then select the PFMEA worksheet.**
- **Using process steps 20 and 25 from the completed Star Process Flow Diagram handout, complete 2 rows of the PFMEA.**

30 Minutes

Use the file **PPAP Training Templates.xls**

Process FMEA (PFMEA)

Tips and Lessons Learned

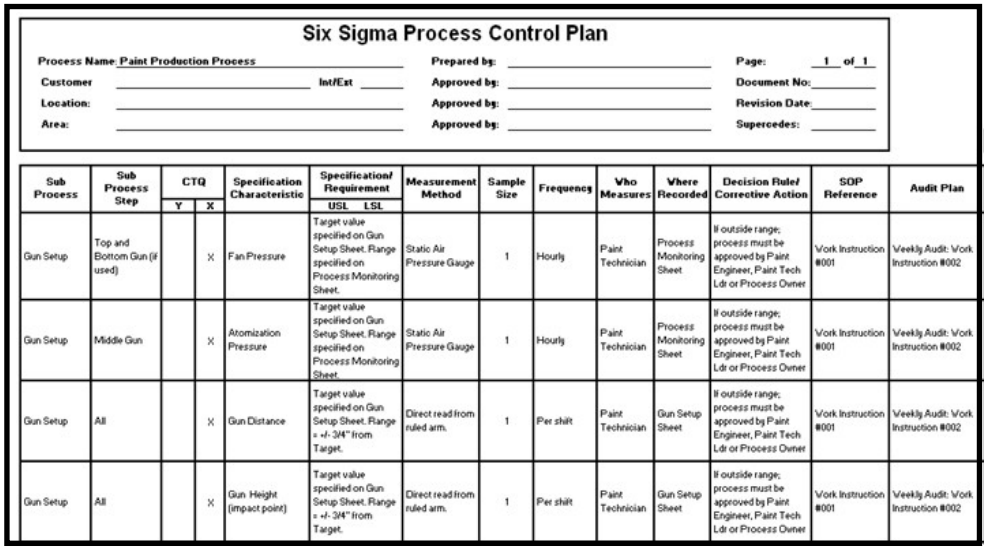
- **Collaborative Effort: Do not try alone, use a group**
- **Very laborious: Time consuming process. Take necessary breaks.**
- **Action items are required for completion**
- **Train team ahead of time by explaining scoring criteria**
- **Proper preparation is needed for meetings**
- **Summarize often: FMEA is a living document**

Reviewers Checklist

- ✓ **Verify there is a system for prioritizing risk of failure such as RPN numbers of 125 or above**
- ✓ **Make sure that high RPN process concerns are carried over into the control plan**
- ✓ **Make sure that all critical failure modes are addressed**
  - **Safety**
  - **Form, fit, function**
  - **Material concerns**

CONTROL PLAN

Control Plan



Six Sigma Process Control Plan

Process Name: Paint Production Process | Prepared by: | Page: 1 of 1
Customer | Int/Ext | Approved by: | Document No:
Location: | Approved by: | Revision Date:
Area: | Approved by: | Supercedes:

Sub Process	Sub Process Step	CTQ Y	CTQ X	Specification Characteristic	Specification/ Requirement USL	Specification/ Requirement LSL	Measurement Method	Sample Size	Frequency	Who Measures	Where Recorded	Decision Rule/ Corrective Action	SOP Reference	Audit Plan
Gun Setup	Top and Bottom Gun (if used)		X	Fan Pressure	Target value specified on Gun Setup Sheet. Range specified on Process Monitoring Sheet.		Static Air Pressure Gauge	1	Hourly	Paint Technician	Process Monitoring Sheet	If outside range; process must be approved by Paint Engineer, Paint Tech Ldr or Process Owner	Work Instruction #001	Weekly Audit: Work Instruction #002
Gun Setup	Middle Gun		X	Atomization Pressure	Target value specified on Gun Setup Sheet. Range specified on Process Monitoring Sheet.		Static Air Pressure Gauge	1	Hourly	Paint Technician	Process Monitoring Sheet	If outside range; process must be approved by Paint Engineer, Paint Tech Ldr or Process Owner	Work Instruction #001	Weekly Audit: Work Instruction #002
Gun Setup	All		X	Gun Distance	Target value specified on Gun Setup Sheet. Range = +/- 3/4" from Target.		Direct read from ruled arm.	1	Per shift	Paint Technician	Gun Setup Sheet	If outside range; process must be approved by Paint Engineer, Paint Tech Ldr or Process Owner	Work Instruction #001	Weekly Audit: Work Instruction #002
Gun Setup	All		X	Gun Height (impact point)	Target value specified on Gun Setup Sheet. Range = +/- 3/4" from Target.		Direct read from ruled arm.	1	Per shift	Paint Technician	Gun Setup Sheet	If outside range; process must be approved by Paint Engineer, Paint Tech Ldr or Process Owner	Work Instruction #001	Weekly Audit: Work Instruction #002

What is It?

A document that describes how to control the critical inputs to continue to meet customer expectations of the output.

Objective or Purpose

- Primary reference source for minimizing process and product variation.
- Description of how teams should react to out-of-control situations.

When to Use It

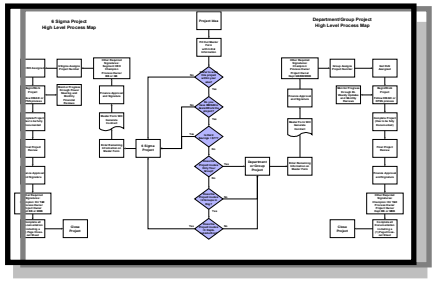
- Implementation of new process
- Following a process change

NOTE

Since processes are expected to be continuously updated and improved, the control plan is a living document!

Control Plan

Tool Interaction



Process Flowchart

Process Steps

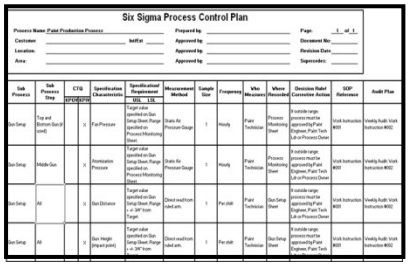
New/Revised Process Steps

Process Step	Key Process Input	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes	O C C	Current Controls	D E T	R P N	E O C
Receive payment	Checks	Delay internal mail	AR balance does not go down	7	Inadequate staffing in mail room	7	None	10	490	
Identify customer	Wire Transfer reference line	Information not supplied	AR balance is past due	10	Customer or bank did not include name and/or account info on wire transfer	5	Acct identifies problem when trying to apply payment	5	250	
Identify Invoice	Checks	Incorrect invoice supplied	Invoice shows outstanding (AR balance does go down)	5	Customer error	5	Customer might catch it when reviewing the next statement	10	250	
Identify Invoice	Checks	Invoice number not supplied	Invoice shows outstanding (AR balance does go down)	5	Customer error	10	Acct identifies problem when trying to apply payment	5	250	

Process FMEA

Process Steps

New/Revised Process Steps



Control Plan

Risk Prioritized Process Steps

Improved Controls

NCR's Control Plan

CONTROL PLAN

Prototype	Pre-Launch	Production		
Control Plan Number		Key Contact/Phone	Date:(Org.)	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	

This is included in the PPAP Playbook!

Control Plan

3 Distinct Phases

CONTROL PLAN

Prototype		Pre-Launch		Production									
Control Plan Number				Key Contact/Phone					Date:(Org.)		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: No.	Characteristics: Product	Characteristics: Process	Special Char. Class	Methods: Product/Process Specification/ Tolerance	Methods: Evaluation /Measurement Technique	Methods: Sample: Size	Methods: Sample: Freq.	Methods: Control Method	Reaction Plan	

3 D

1. Prototype – dimension material ar will occur

3

2. Pre-Lau dimensi materia will occu *full Proc*

3 Distinct Phases

3. Production – a comprehensive documentation of product/process characteristics, process controls, tests, and measurement systems that will occur during mass production

Control Plan

Administrative Section

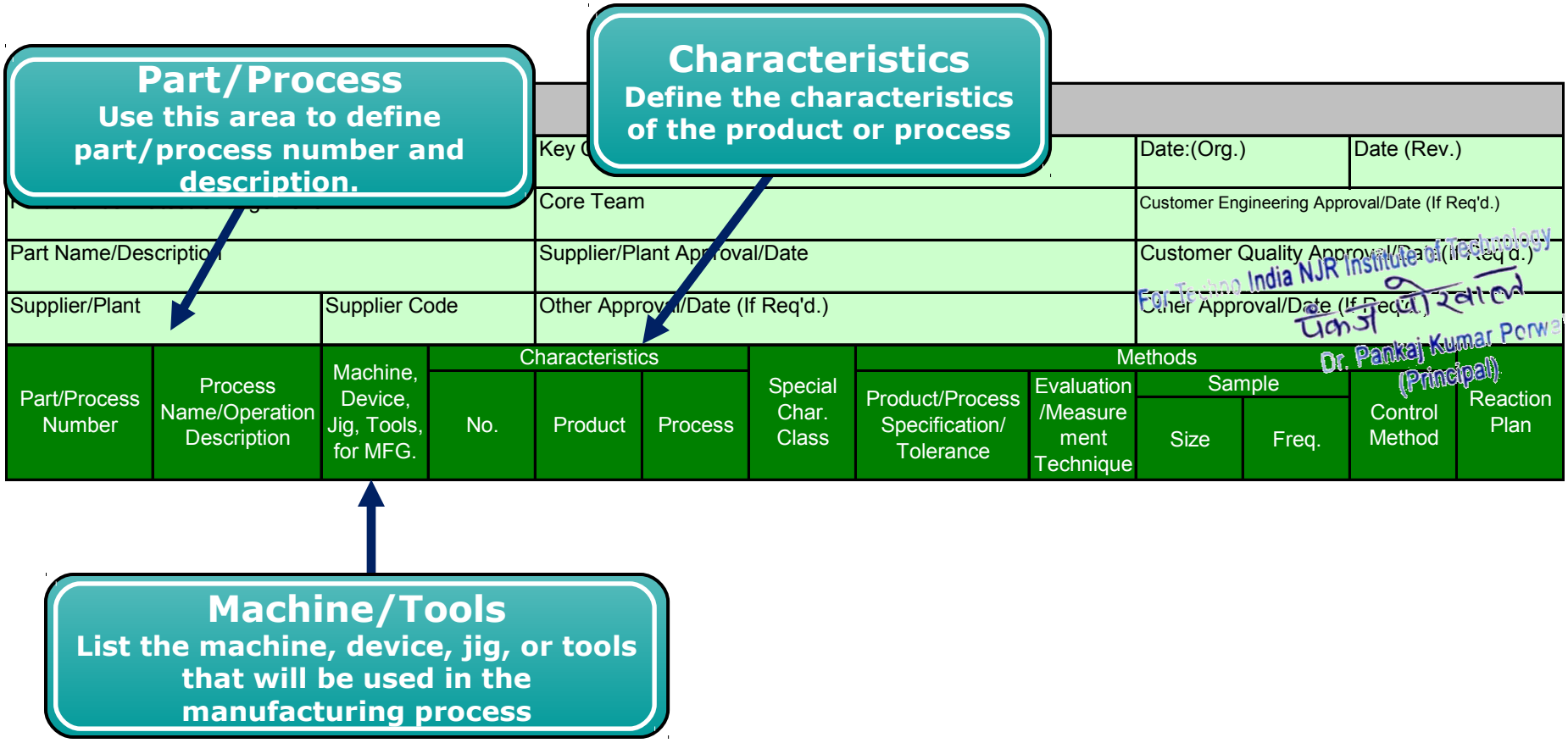
CONTROL PLAN

Prototype	Pre-Launch	Production											
Control Plan Number			Key Contact/Phone						Date:(Org.)		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		Sample				
			No.	Product	Process		Product/Process Specification/ Tolerance	Evaluation /Measurement Technique	Size	Freq.	Control Method	Reaction Plan	

Administrative Section
Identifies part number and description, supplier, required approval signatures, and dates.

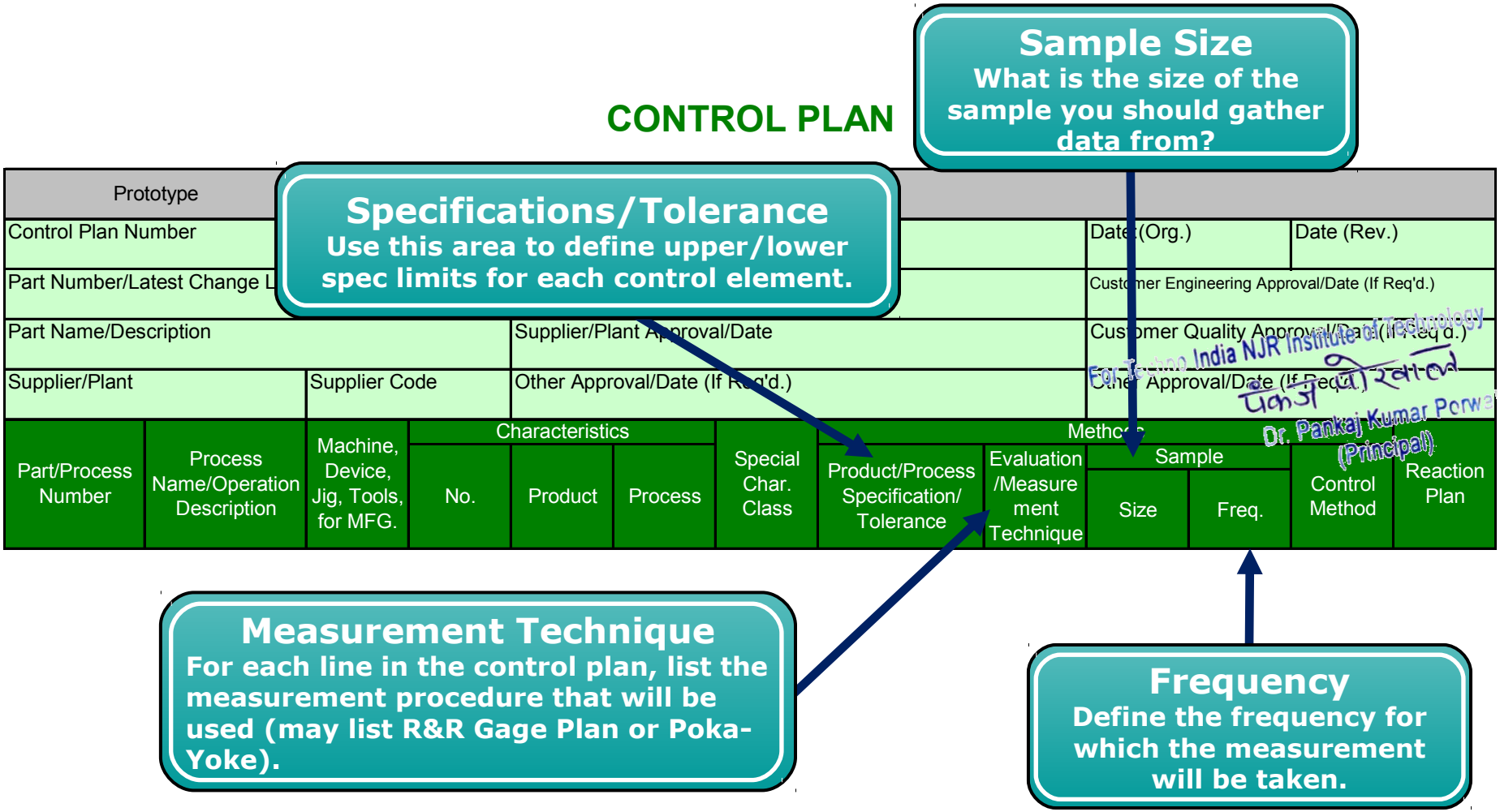
Control Plan

Process, Machine/Tools, Characteristics



Control Plan

Specifications, Measurement, Sample Size & Frequency



Control Plan

Control Method, Reaction Plan

CONTROL PLAN

Prototype	Pre-Launch	Production		
Control Plan Number		Key Contact/Phone	Date:(Org.)	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				Control Method	Reaction Plan
			No.	Product	Process		Product/Process Specification/ Tolerance	Evaluation /Measurement Technique	Sample Size	Sample Freq.		

Control Method
Method that will be used to control the process

Reaction Plan
Actions to be taken if controls fail

Control Plan

Audit Plans

- **Audit plans should be included in the control plan as a separate line.**
- **Auditing is an important tool for control.**
- **Process auditing should be a key element of the quality system of a business.**
- **Audits generally cover:**
  - **Effectiveness of controls**
  - **Control plan (say) vs. what is actually done (do)**
- **Audits should be objective (done by internal or external third parties if possible).**
- **Audit frequencies should be based on balancing level of risk (FMEA) and cost.**

Control Plan – Example

A supplier manufactures a circuit board with electronic components soldered on the board. Properly soldered connections are the major product characteristics. Two major process characteristics for the wave solder machine are solder level and flux concentration. An automated feeder controls the solder level by sensing the level of solder and feeding in additional solder as the level is reduced. This characteristic is measured 100% by checking electrically for continuit… tested for the concentration level.

Control Method
Product = Automated inspection
Process = x-MR chart

Characteristics

Specifications/Tolerance
Product = 2.0 +/- 0.25 mc
Process = Standard #302B

Reaction Plan
Product = Adjust and retest
Process = Segrega… and retest

Part 54321231 / D											
Part Name/Description Electronic Circuit Board				Supplier/Plant Approval/Date				Customer Quality Approval/Date(If Req'd.)			
Supplier/Plant ACR Control		Supplier Code 439412		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 No.	Product		Methods		Sample Size	Sample Freq.	Control Method	Reaction Plan
2					0 +/- .25 mc	Sensor continuity check	100%	Continuous	Automated inspection (error proofing)	Adjust and retest
					andard #302B	Test sampling lab environment	1 pc	4 hours	x-MR chart	Segregate and retest

3 Distinct Phases
Production

Measurement Technique
Product = Sensor continuity check
Process = Test sampling lab environment

Control Plan Exercise

Instructions

- **Open the PPAP Training Templates.xls file, then select the Control Plan worksheet.**
- **Using the completed Star Process Flow Diagram (process steps 20 and 25) and the completed PFMEA, complete 2 rows of the Control Plan.**
- **Document potential problems that might be encountered and potential solutions with your team.**

20 Minutes

Use the file **PPAP Training Templates.xls**

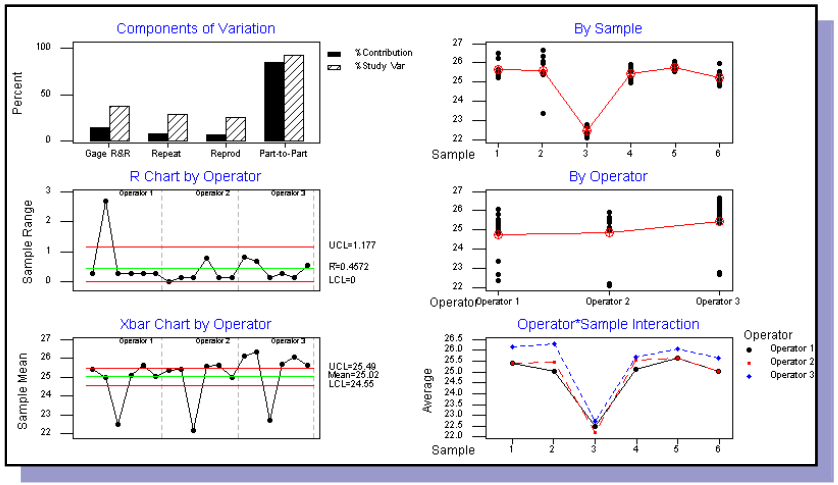
Control Plan

Reviewer's Checklist

- ✓ **Use process flow diagram and PFMEA to build the control plan; keep them aligned**
- ✓ **Controls must be used to be effective. Keep it simple.**
- ✓ **Ensure that the control plan is in the document control system of the business**
- ✓ **Good control plans address:**
  - ➢ **All testing requirements - dimensional, material, and performance**
  - ➢ **All product and process characteristics at every step throughout the process**
- ✓ **The control method should be based on an effective analysis of the process**
  - ➢ **Such as SPC, Error Proofing, Inspection, Sampling Plan**
- ✓ **Control plans should reference other documentation**
  - ➢ **Specifications, tooling, etc.**

MEASUREMENT SYSTEM ANALYSIS (MSA)

Measurement System Analysis (MSA)



When to Use It

- On the critical inputs and outputs prior to collecting data for analysis.
- For any new or modified process in order to ensure the quality of the data.

Who Should be Involved

Everyone that measures and makes decisions about these measurements should be involved in the MSA.

What is It?

An MSA is a statistical tool used to determine if a measurement system is capable of precise measurement.

Objective or Purpose

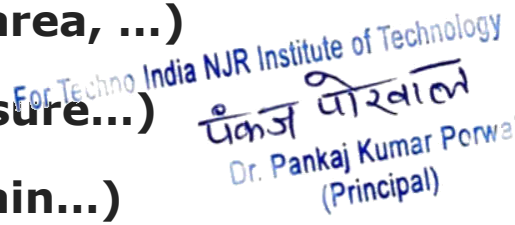
- To determine how much error is in the measurement due to the measurement process itself.
- Quantifies the variability added by the measurement system.
- Applicable to attribute data and variable data.

IMPORTANT!

Measurement System Analysis is an analysis of the measurement process, *not* an analysis of the people!!

Attribute and Variable MSA

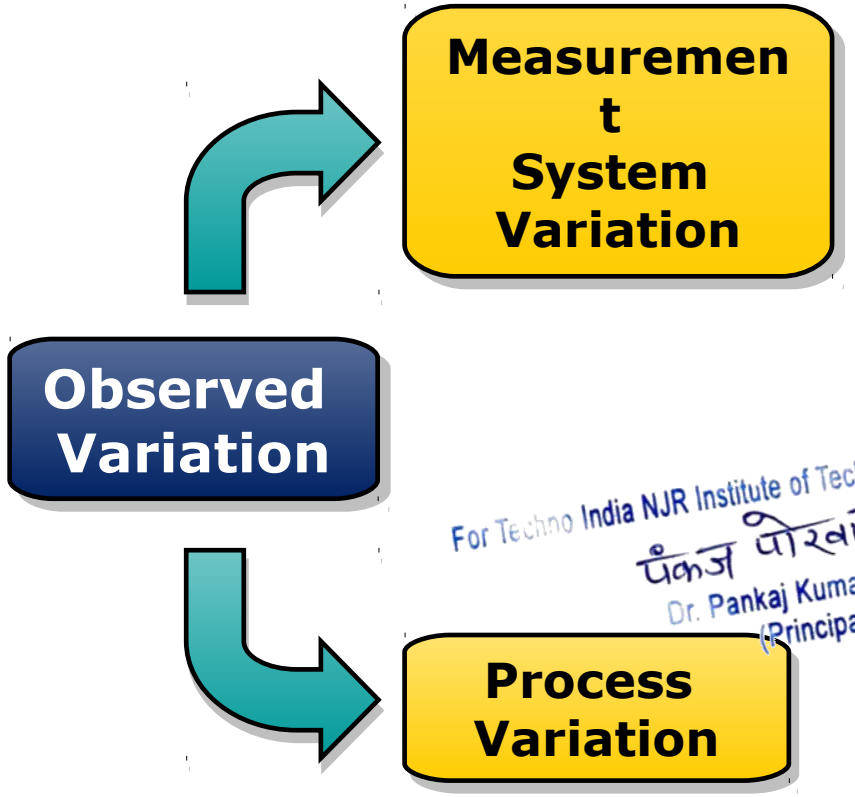
- **Attribute Data Examples**:
  - **Count, Pass/fail, yes/no, red/green/yellow, timekeeping buckets**
- **Variable Data Examples**:
  - **Physical measurement (length, width, area, …)**
  - **Physical conditions (temperature, pressure…)**
  - **Physical properties (strength, load, strain…)**
  - **Continuous or non-ending**



Unless approved by an NCR SQE, attribute data is not acceptable for PPAP submission

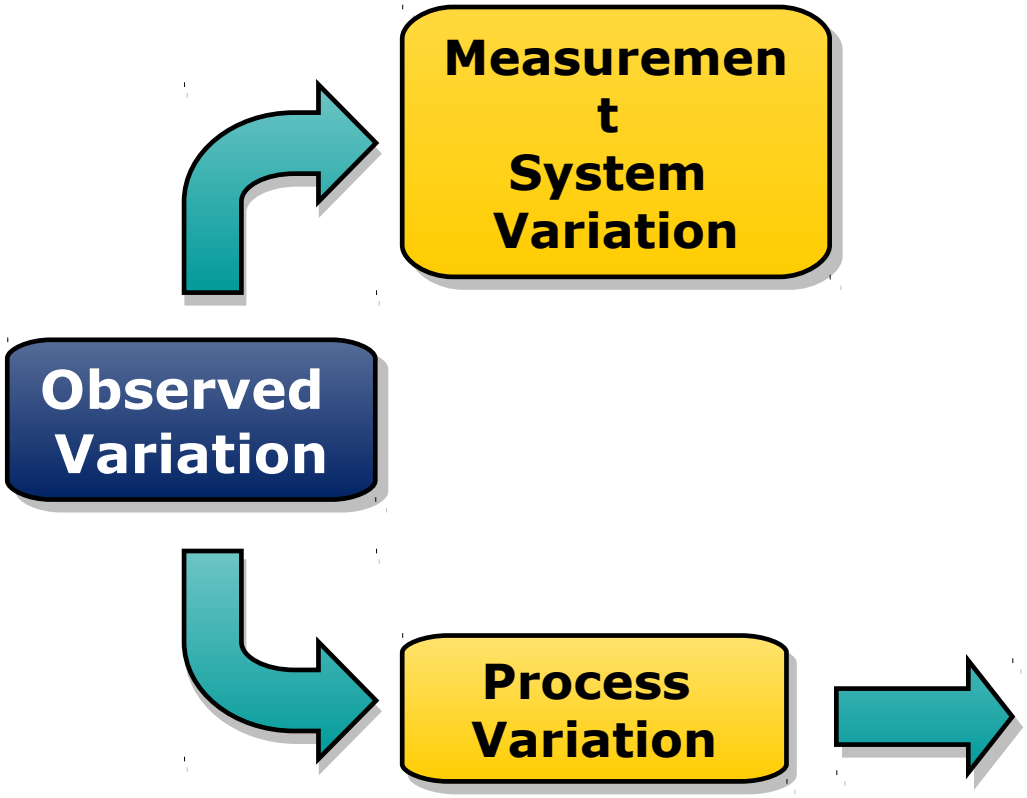
Measurement System Analysis (MSA)

The observed variation in process output measurements is not simply the variation in the process itself; it is the variation in the process plus the variation in measurement that results from an inadequate measurement system.



Conducting an MSA reduces the likelihood of passing a bad part or rejecting a good part

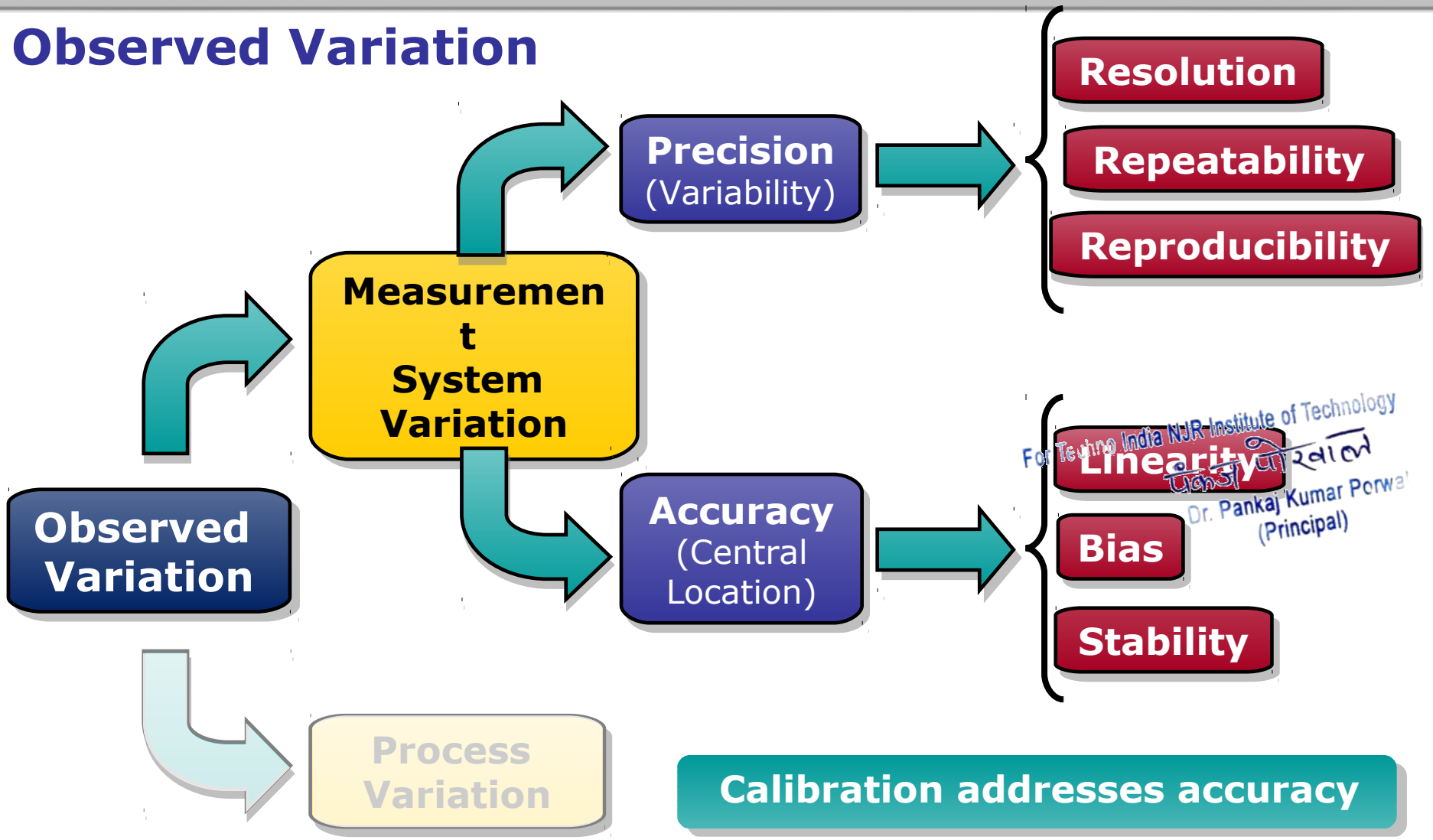
Observed Variation



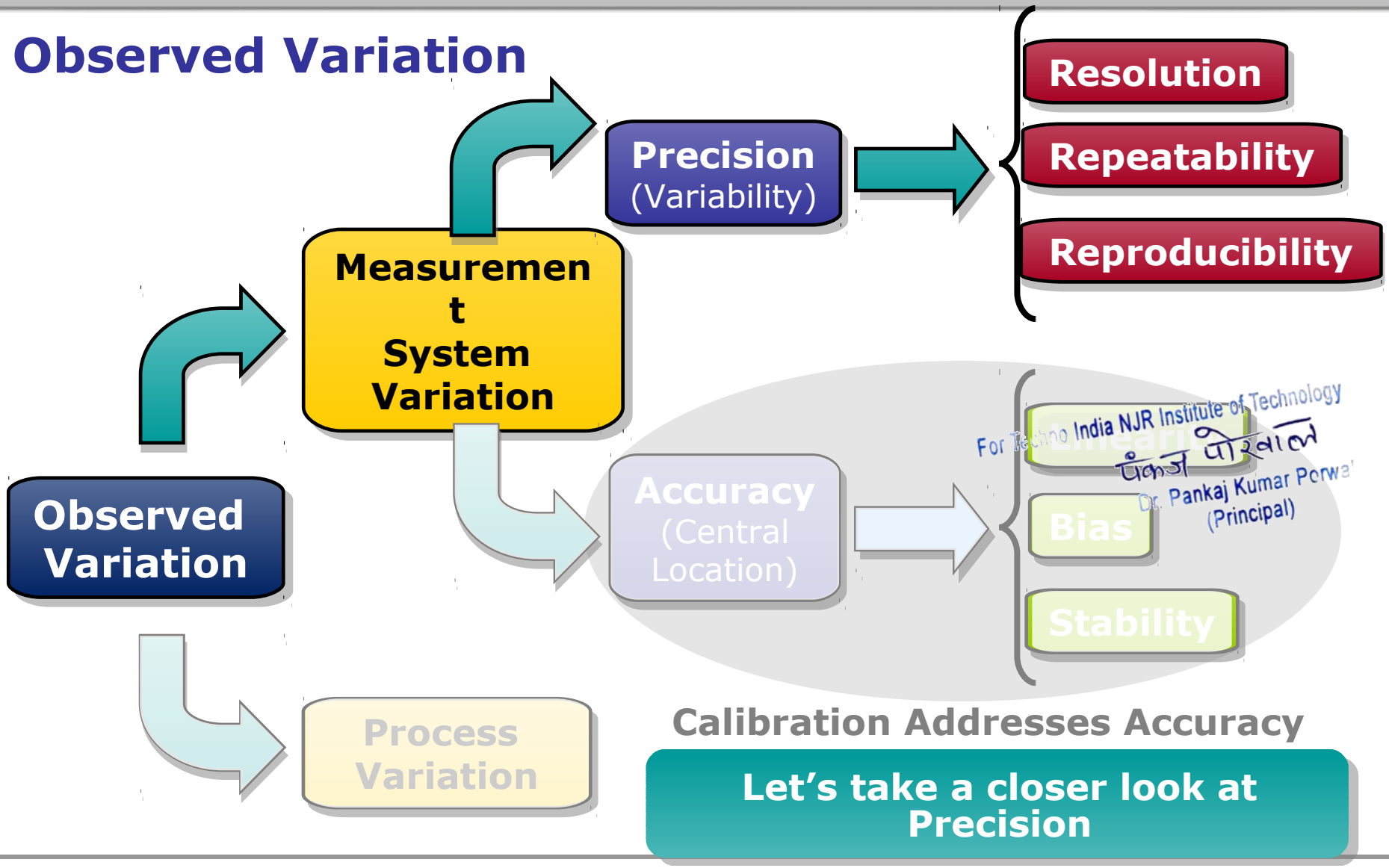
The output of the process measured by:

- **Cycle time**
- **Dimensional data**
- **Number of defects and others**

Measurement System Analysis (MSA)



Measurement System Analysis (MSA)



Measurement System Analysis (MSA)

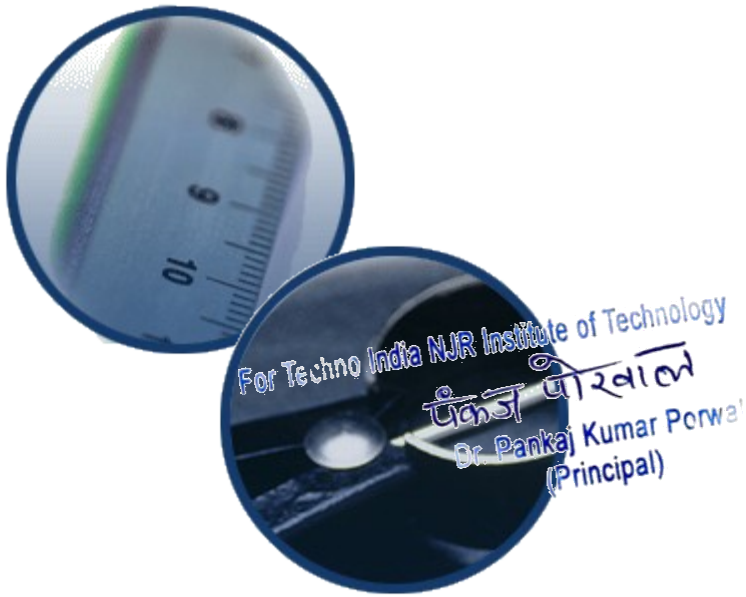
Resolution

Error in Resolution

The inability to detect small changes.

Possible Cause

Wrong measurement device selected - divisions on scale not fine enough to detect changes.



Measurement System Analysis (MSA)

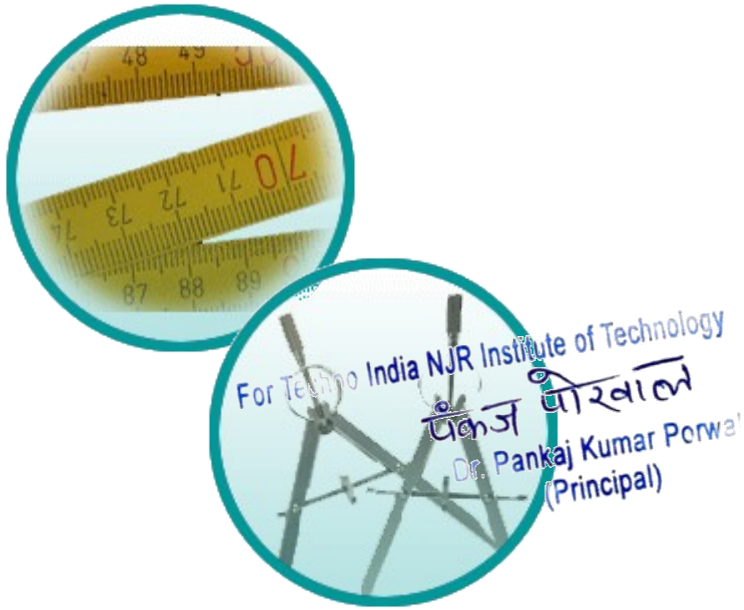
Repeatability

Error in Repeatability

The inability to get the same answer from repeated measurements made of the same item under absolutely identical conditions.

Possible Cause

Lack of standard operating procedures (SOP), lack of training, measuring system variablilty.



Equipment Variation

Measurement System Analysis (MSA)

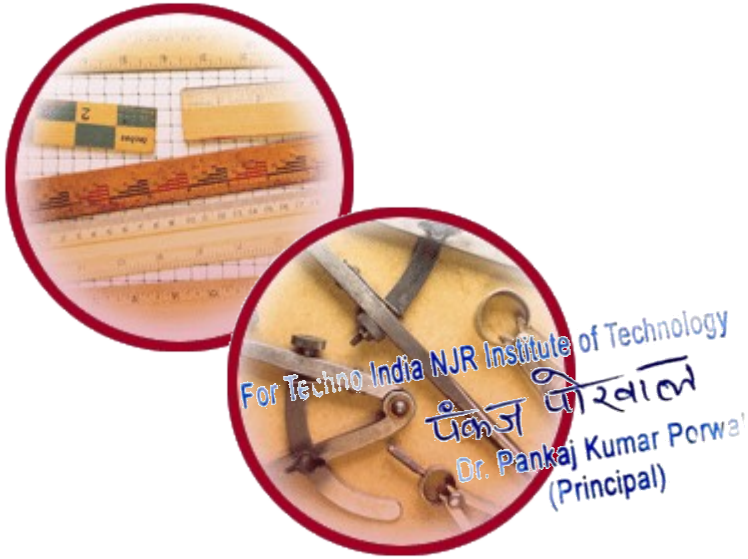
Reproducibility

Error in Reproducibility

The inability to get the same answer from repeated measurements made under various conditions from different inspectors.

Possible Cause

Lack of SOP, lack of training.



Appraiser Variation

Variable MSA – Gage R&R Study

- **Gage R&R is the combined estimate of measurement system Repeatability and Reproducibility**
- **Typically, a 3-person study is performed**
  - **Each person randomly measures 10 marked parts per trial**
  - **Each person can perform up to 3 trials**
- **There are 3 key indicators**
  - **EV or Equipment Variation**
  - **AV or Appraiser Variation**
  - **Overall % GRR**

Variable MSA – NCR's Gage R&R Form

Gage Repeatability and Reproducibility

This spreadsheet is designed for up to three operators, three trials, and ten samples. Enter data ONLY in gray shaded cells.

Number of operators
Number of trials
Number of samples

Upper specification limit
Lower specification limit

Data	Operator 1				Operator 2				Operator 3			
	Trial				Trial				Trial			
Sample #	1	2	3	Range	1	2	3	Range	1	2	3	Range
1				0.000				0.000				0.000
2				0.000								
3				0.000								
4				0.000								
5				0.000								
6				0.000								
7				0.000								
8				0.000				0.000				0.000
9				0.000				0.000				0.000
10				0.000				0.000				0.000
Range average				0.000				0.000				0.000
Sample average				#DIV/0!				#DIV/0!				#DIV/0!

Automatically calculates EV, AV, and % GRR!

Average range 0.000
X-bar range #DIV/0!

Repeatability (EV)	#N/A
Reproducibility (AV)	#DIV/0!
Repeatability and Reproducibility (R&R)	#N/A
Control limit for individual ranges	#N/A

Tolerance analysis

#N/A
#DIV/0!
#N/A

Note: any ranges beyond this limit may be the result of assignable causes. Identify and correct. Discard values and recompute statistics.

Do not modify this table

Trials	D4	K1	K2
2	3.27	4.56	3.65
3	2.58	3.05	2.7

Included in PPAP Playbook!

Variable MSA – Gage R&R Steps

1. **Select 10 items that represent the full range of long-term process variation.**
2. **Identify the appraisers.**
3. **If appropriate, calibrate the gage or verify that the last calibration date is valid.**
4. **Open the Gage R&R worksheet in the PPAP Playbook to record data.**
5. **Have each appraiser assess each part 3 times (trials – first in order, second in reverse order, third random).**
6. **Input data into the Gage R&R worksheet.**
7. **Enter the number of operators, trials, samples and specification limits**
8. **Analyze data in the Gage R&R worksheet.**
9. **Assess MSA trust level.**
10. **Take actions for improvement if necessary.**

Steps 1 and 2: Variable MSA - Gage R&R

Select 10 items that represent the full range of long-term process variation.

Identify the appraisers.

- **Should use individuals that actually do the process being tested.**
- **Can also include other appraisers (supervisors, etc.).**
- **Should have a minimum of 3 appraisers.**

Steps 3 and 4: Variable MSA – Gage R&R

Step 3

If appropriate, calibrate the gage or verify that the last calibration date is valid.

Step 4

Open the Gage R&R worksheet in the PPAP Playbook to record the data

Step 5: Variable MSA – Gage R&R

Step 5

Have <u>each</u> appraiser assess <u>each</u> item 3 times.

- **Each appraiser has to work independently.**
- **Items should be evaluated in random order.**
- **After <u>each</u> appraiser completes the first evaluation of all items – repeat the process at least 2 more times.**
- ***Do not let the appraisers see any of the data during the test !!***

Steps 6 and 7: Variable MSA – Gage R&R

Step 6

Input data into the Gage R&R worksheet

Step 7

Enter the number of operators, trials, samples and specification limits

Steps 8 and 9: Variable MSA – Gage R&R

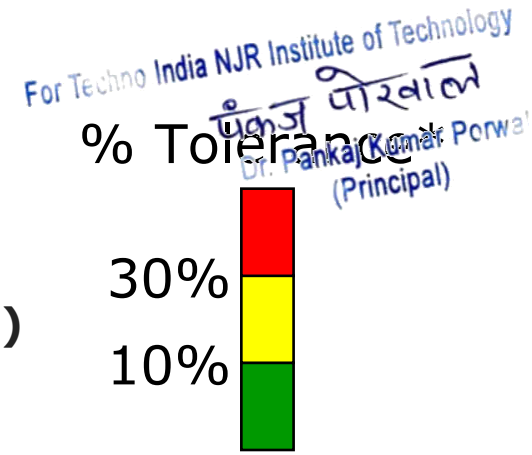
Step 8

Analyze data in the Gage R&R worksheet

Step 9

Assess MSA Trust Level.

- **Red: > 30%** (fail)
- **Yellow: 10-30%** (marginal)
- **Green: < 10%** (pass)



Step 10: Variable MSA – Gage R&R

Step 10

If the Measurement System needs improvement:

- **Brainstorm with the team for improvement solutions.**
- **Determine best "practical solution" (may require some experimentation).**
- **Pilot the best solution (PDSA)**
- **Implement best solution – train employees.**
- **Re-run the study to verify the improvement.**

Variable MSA – Gage R&R Example

Problem Statement

- **The sulfuric acid concentration in process tank 8 is measured at least once per day**
- **Additions/deletions of chemicals and decisions to shut down the process are dependent on these results.**
- **Based on current data, we need to do an MSA.**

MSA Process

A Gage R&R was conducted in order to validate the process.

MSA Parameters

- (3) Operators
- (3) Trials
- (10) Samples

Variable MSA – Gage R&R Example

Entered the number of operators, trials, and samples

Entered upper and lower specification limits

be appraisers

Had each appraiser measure each sample 3 times

Results calculated automatically

Selected 10 samples to be measured

Gage Repea

This spreadsheet is designed for up to three op LY in gray shaded cells.

Number of operators		Upper specification limit	27
Number of trials	3	Lower specification limit	22
Number of samples	10		

Data	Operator 1				Operator 2				Operator 3			
	Trial				Trial				Trial			
Sample #	1	2	3	Range	1	2	3	Range	1	2	3	Range
1	25.250	25.540	25.390	0.290	25.390	25.680	25.390	0.290	25.390	25.680	25.390	0.290
2	25.420	25.540	24.960	0.580	25.540	25.540	24.960	0.580	25.540	25.540	24.960	0.580
3	22.370	22.370	22.670	0.300	22.220	22.520	22.670	0.450	22.220	22.520	22.670	0.450
4	24.960	25.250	25.110	0.290	25.110	25.680	25.250	0.570	25.110	25.680	25.250	0.570
5	25.540	25.540	25.820	0.280	25.540	25.680	25.540	0.140	25.540	25.680	25.540	0.140
6	24.610	25.110	24.820	0.500	24.960	26.700	25.110	1.740	24.960	26.700	25.110	1.740
7	24.440	24.260	24.110	0.330	25.250	25.540	25.110	0.430	25.250	25.540	25.110	0.430
8	26.100	26.800	26.100	0.700	25.540	25.540	25.540	0.000	25.540	25.540	25.540	0.000
9	25.390	25.390	25.390	0.000	26.380	26.660	26.220	0.440	26.380	26.660	26.220	0.440
10	25.680	25.820	25.540	0.280	23.900	25.250	25.110	1.350	23.900	25.200	23.870	1.330
				0.355				0.516				0.578
				25.043				25.211				25.248

X-bar range	0.205

Repeatability (EV)	1.4732
Reproducibility (AV)	0.4827
Repeatability and Reproducibility (R&R)	1.5502
Control limit for individual ranges	1.2461

Note: any ranges beyond this limit may be the result of assignable causes. Identify and correct. Discard values and recompute statistics.

Tolerance analysis

29.46%
9.65%
31.00%

Variable MSA – Gage R&R Example

Gage Repeatability and Reproducibility

This spreadsheet is designed for up to three operators, three trials, and ten samples. Enter data ONLY in gray shaded cells.

Number of operators	3	Upper specification limit	27
Number of trials	3	Lower specification limit	22
Number of samples	10		

Data	Operator 1				Operator 2				Operator 3			
	Trial				Trial				Trial			
Sample #	1	2	3	Range	1	2	3	Range	1	2	3	Range
1	25.250	25.540	25.390	0.290	25.390	25.390	25.390	0.000	25.680	26.330	26.520	0.840
2	25.420	25.540	24.960	0.580	25.540	25.520	25.470	0.070	26.380	26.130	25.960	0.420
3	22.370	22.370	22.670	0.300	22.220	22.180	22.220	0.040	22.670	22.810	22.670	0.140
4	24.960	25.250	25.110	0.290	25.110	25.680	25.920	0.810	25.680	26.200	25.540	0.660
5	25.540	25.540	25.820	0.280	25.540	25.680	25.680	0.140	25.730	25.960	25.890	0.230
6	24.610	25.110	24.820	0.500	24.960	26.700	25.110	1.740	25.390	25.540	25.960	0.570
7	24.440	24.260	24.110	0.330	25.250	25.540	25.420	0.290	25.250	25.830	25.390	0.580
8	26.100	26.800	26.100	0.700	25.540	25.540	25.820	0.280	25.110	25.680	25.920	0.810
9	25.390	25.390	25.390	0.000	26.380	26.660	26.220	0.440	25.250	25.540	25.390	0.290
10	25.680	25.820	25.540	0.280	23.900	25.250	25.110	1.350	24.200	23.870	22.960	1.240
Range average				0.355				0.516				0.578
Sample average				25.043				25.211				25.248

Repeatability & Reproducibility = R&R

	Tolerance analysis
Repeatability (EV)	29.46%
Reproducibility (AV)	9.65%
Repeatability and Reproducibility (R&R)	31.00%
Control limit for individual ranges	

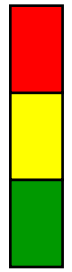
Note: any r... of assignab... values and ...

% Tolerance is > 30%
MSA fails!

% Tolerance*

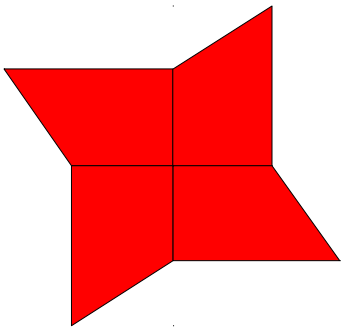
30%

10%



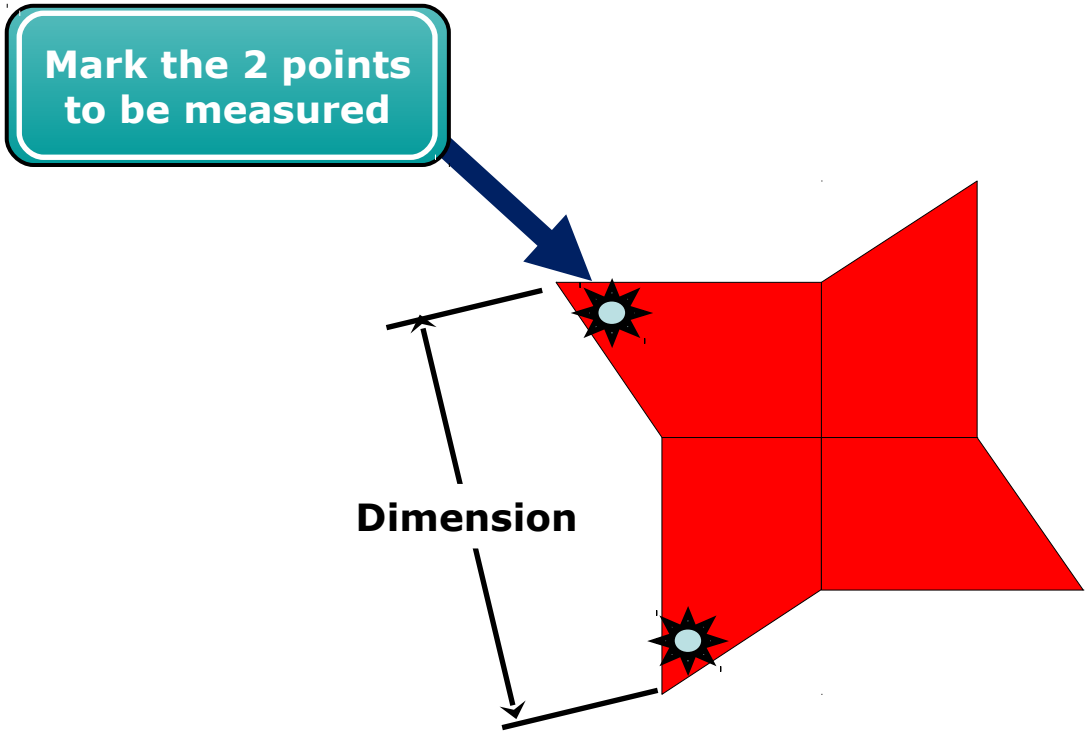
Gage R&R Exercise - Setup Instructions

- **Divide into teams**
- **Distribute stars (10 per team), measurement devices (1 per team), and markers (1 per team).**
- **Number the stars from 1-10.**
- **Mark the 2 points to be measured on each star (see diagram on next page)**
- **Determine and document the measurement process.**
- ***Be sure everyone has a clear understanding of the process.***
- **Determine roles.**
  - **(3) inspectors, (1) data recorder, (1) customer**



Gage R&R Exercise - Dimensional Information

Each star will be measured as shown.



Gage R&R Exercise – Inspection Instructions

1. **All inspectors need to wait outside the room when it is not their turn to evaluate the stars.**
2. **Open the PPAP Training Templates.xls file, then select the Gage R&R worksheet to record the data.**
3. **Round 1**
   Have the 1st inspector come in the room and measure all 10 stars in order. Data collector record the data in the Gage R&R worksheet.
   - ***Do not give any additional information to the inspector***

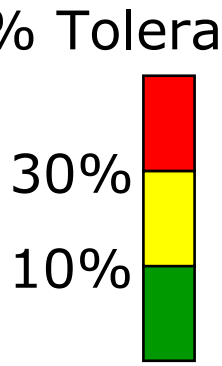
1. **Repeat Step 3 with the 2nd inspector**
2. **Repeat Step 3 with the 3rd inspector**

6. **Round 2**
   Change the inspection to reverse order and repeat.
7. **Round 3**
   Change the inspection to random order and repeat.

Use the file **PPAP Training Templates.xls**

Gage R&R Exercise - Analysis Instructions

1. **Complete the top section of the Gage R&R worksheet**
   - **Enter the number of operators, trials, and samples**
   - **Enter the upper and lower specification limit**
2. **Assess MSA Trust Level.**
   - **Red: > 30% (fail)**
   - **Yellow: 10-30% (marginal)**
   - **Green: < 10% (pass)**



3. **Interpret results - are improvements required?**

45 Minutes

Use the file **PPAP Training Templates.xls**

Tips and Lessons Learned

- ✓ **Important: An MSA is an analysis of the process, not an analysis of the people. If an MSA fails, the process failed.**
- ✓ **A Variable MSA provides more analysis capability than an Attribute MSA. For this and other reasons, always use variable data if possible.**
- ✓ **The involvement of people is the key to success.**
  - ✓ **Involve the people that actually work the process**
  - ✓ **Involve the supervision**
  - ✓ **Involve the suppliers and customers of the process**
- ✓ **An MSA primarily addresses precision with limited accuracy information.**

Reviewer's Checklist

- ✓ If the gage/inspection affects quality, then conduct a Gage R&R
- ✓ Make sure the study is recent - less than 1 year
- ✓ Compare the control plan gages against the Gage R&Rs
- ✓ If you question that gage, then
  - Question the technique and part sampling
  - Ask for additional studies

DIMENSIONAL RESULTS

Dimensional Results

FAI Non-Critical Dimensions

Date:	*Supplier Name:*	*Date Code:*
Part Number:	*Facility Location:*	*Inspected By:*
Revision:	*Supplier Code:*	*Verified By:*

The number of non-critical data points required for part qualification is 5. The non-critical data points must be taken from the same 35-piece sample as the critical data points. Five parts *from a production run* must be shipped to NCR for verification of form, fit, and function. The same 5 parts will be used to verify both critical and non-critical dimensions. The supplier must clearly identify which of the 35 parts are being shipped. Non-critical dimensional results for the 5 parts being shipped must be entered below. Critical dimensional results must be entered into the "FAI Critical Dimensions" worksheet. The supplier should make every effort to ship 5 parts that represent both the low and high ends of the specifications for the non-critical dimensions.

Cpk less than 1.33 will require action for improvement

Print zone or spec note	Nominal Value	Tol +	Tol -	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Cp	Cpk	Pass/Fail
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									#DIV/0!	#DIV/0!	
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List Gage R&R value: **Name and ID of gage(s) used for measurement:**

What is It?

Evidence that dimensional verifications have been completed and results indicate compliance with specified requirements.

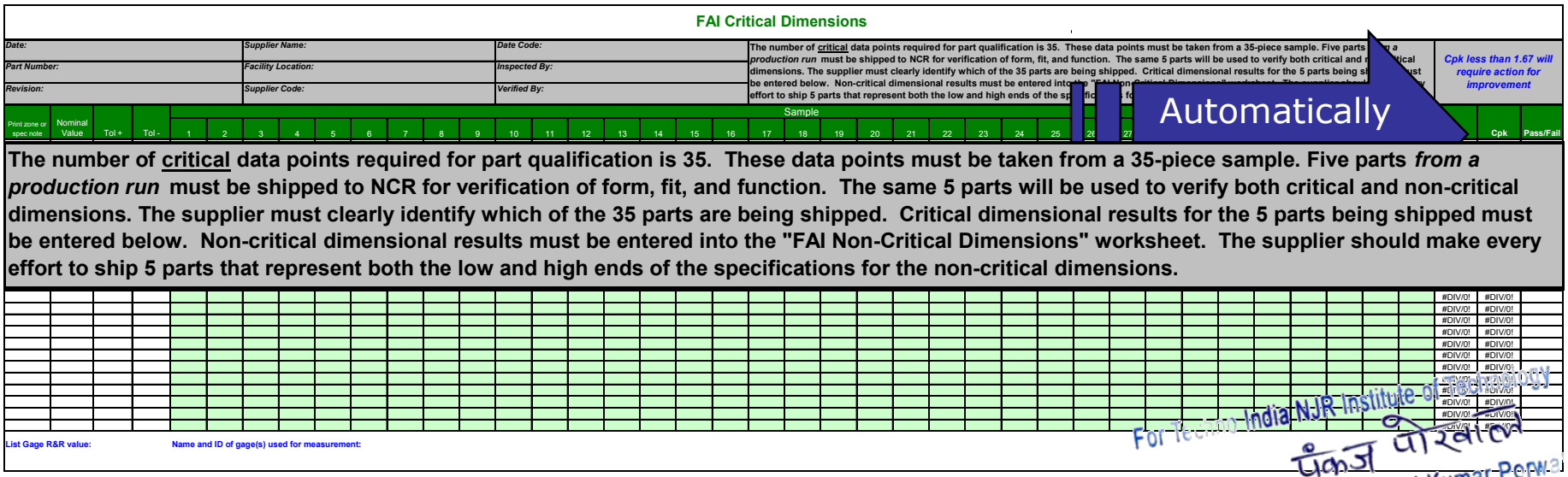
Objective or Purpose

- To show conformance to the customer part print on dimensions and all other noted requirements.

When to Use It

- For each unique manufacturing process (e.g., cells or production lines and all molds, patters, or dies

NCR Dimensional Report (Critical)



FAI Critical Dimensions

Date:	*Supplier Name:*	*Date Code:*
Part Number:	*Facility Location:*	*Inspected By:*
Revision:	*Supplier Code:*	*Verified By:*

Cpk less than 1.67 will require action for improvement

Automatically

The number of <u>critical</u> data points required for part qualification is 35. These data points must be taken from a 35-piece sample. Five parts *from a production run* must be shipped to NCR for verification of form, fit, and function. The same 5 parts will be used to verify both critical and non-critical dimensions. The supplier must clearly identify which of the 35 parts are being shipped. Critical dimensional results for the 5 parts being shipped must be entered below. Non-critical dimensional results must be entered into the "FAI Non-Critical Dimensions" worksheet. The supplier should make every effort to ship 5 parts that represent both the low and high ends of the specifications for the non-critical dimensions.

Print zone or spec note	Nominal Value	Tol +	Tol -	Sample																																			Cpk	Pass/Fail
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27											
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List Gage R&R value: **Name and ID of gage(s) used for measurement:**

Requires 35 data points

Cpk must be greater than or equal to 1.67

This is included in the PPAP Playbook!

NCR Dimensional Report (Non-Critical)

FAI Non-Critical Dimensions

Date:	*Supplier Name:*	*Date Code:*
Part Number:	*Facility Location:*	*Inspected By:*
Revision:	*Supplier Code:*	*Verified By:*

The number of non-critical data points required for part qualification is 5. The non-critical data points must be taken from the same 35-piece sample as the critical data points. Five parts *from a production run* must be shipped to NCR for verification of form, fit, and function. The same 5 parts will be used to verify both critical and non-critical dimensions. The supplier must clearly identify which of the 35 parts are being shipped. Non-critical dimensional results for the 5 parts being shipped must be entered below. Critical dimensional results must be entered into the "FAI Critical Dimensions" worksheet. The supplier should make every effort to ship 5 parts that represent both the low and high ends of the specifications for the non-critical dimensions.

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Cpk must be greater than or equal to 1.33

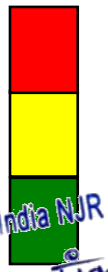
This is included in the PPAP Playbook!

List Gage R&R value: **Name and ID of gage(s) used for measurement:**

Acceptance Criteria

Acceptance criteria for critical vs. non-critical characteristics

	Critical	Non-Critical	Decision
Red (Bad)	<1.33	<1.00	
Yellow (OK)	1.33-1.67	1.00-1.33	
Green (Good)	>1.67	>1.33	



Cpk must be greater than or equal to 1.67 for *critical* processes

Cpk must be greater than or equal to 1.33 for *non-critical* processes

NCR Dimensional Report Example

FAI Non-Critical Dimensions

Date:	***Supplier Name:***	***Date Code:***
Part Number:	***Facility Location:***	***Inspected By:***
Revision:	***Supplier Code:***	***Verified By:***

The number of non-critical data points required for part qualification is 5. The non-critical data points must be taken from the same 35-piece sample as the critical data points. Five parts *from a production run* must be shipped to NCR for verification of form, fit, and function. The same 5 parts will be used to v dime ly id a mens sh b s mus l Di supplier shou make eve effort to shi low specificatio r the no ritical dimensions.

Nominal **Tolerance** **Sample Data** **Cp & Calcula** **Pass**

Cpk less than 1.33 will require action for improvement

Print zone or spec note	Nominal Value	Tol +	Tol -	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Cp	Cpk	Pass/Fail
	35	0.50	0.50	34.86	34.78	34.88	34.86	34.82	4.167	2.833	Pass
	76	0.50	0.50	75.96	76.08	75.92	75.93	76.09	2.017	2.001	Pass
	3	0.50	0.50	3.175	3.18	3.156	3.168	3.178	17.118	11.250	Pass
	3	0.50	0.50	3.18	3.156	3.178	3.175	3.18	16.40	10.703	Pass
	3	0.50	0.50	3.18	3.175	3.174	3.18	3.156	16.83	11.011	Pass
	3	0.50	0.50	3.156	3.18	3.173	3.175	3.18	16.8 2	11.034	Pass

Cpk > 1.33 for all *non-critical* dimensions = Pass!

Dimensional Results

Reviewer's Checklist

- ✓ **Thirty-five critical data points & 5 non-critical data points are required for part qualification**
- ✓ **Critical and non-critical data points must be taken from the same 35-piece sample**
- ✓ **Five parts from a production run must be shipped to NCR for verification of form, fit, and function**
- ✓ **The same 5 parts will be used to verify both critical and non-critical dimensions**
- ✓ **Supplier must clearly identify which of the 35 parts are being shipped**
- ✓ **Supplier should make every effort to ship 5 parts that represent both the low and high ends of the specifications for non-critical dimensions**
- ✓ **Capability must be greater than 1.67 for critical dimensions and greater than 1.33 for non-critical dimensions**

RECORDS OF MATERIAL / PERFORMANCE TEST RESULTS

Records of Material/Performance Test Results

Material Test Results

- **The supplier shall perform tests for all parts and product materials when *chemical, physical, or metallurgical* requirements are specified by the design record or Control Plan**
  - **For products with NCR-developed material specifications and/or an NCR-approved supplier list, the supplier shall procure materials and/or services from suppliers on that list**

Performance Test Results

- **The supplier shall perform tests for all parts or product materials when *performance or functional* requirements are specified by the design record or Control Plan**

Material Results

Production Part Approval - Material Results

Supplier		Part Number	Revision Level
Laboratory ☐ Outside laboratory ☐ In-house testing	Name of Laboratory	Part Name	

Type of Test	Material Spec. No./Date/Specification	Supplier Test Results	OK	Not OK

Signature	Title	Date

Material Results shall include:

- ✓ The name of the laboratory that conducted the test
- ✓ The type of test that was conducted
- ✓ The number, date, and specification to which the part was tested
- ✓ The actual test results

Module Test Results

Production Part Approval - Module Test Results

Supplier			Part Number	Revision Level
Laboratory	☐ Outside laboratory ☐ In-house testing	Name of Laboratory	Part Name	

Type of Test	Test description	Parameters Tested	Supplier Test Results	OK	Not OK

Signature	Title	Date

Module Test Results shall include:

- ✓ The name of the laboratory that conducted the test
- ✓ The type of test that was conducted
- ✓ A description of the test
- ✓ The parameters tested
- ✓ The actual test results

INITIAL PROCESS STUDY

Initial Process Study

PPAP Levels for Submission & Retention

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

S = The supplier shall submit to designated customer product approval activities and retain a copy of records or documentation items at appropriate locations, including manufacturing

R = The supplier shall retain at appropriate locations, including manufacturing, and make **readily** available to the customer representative upon request

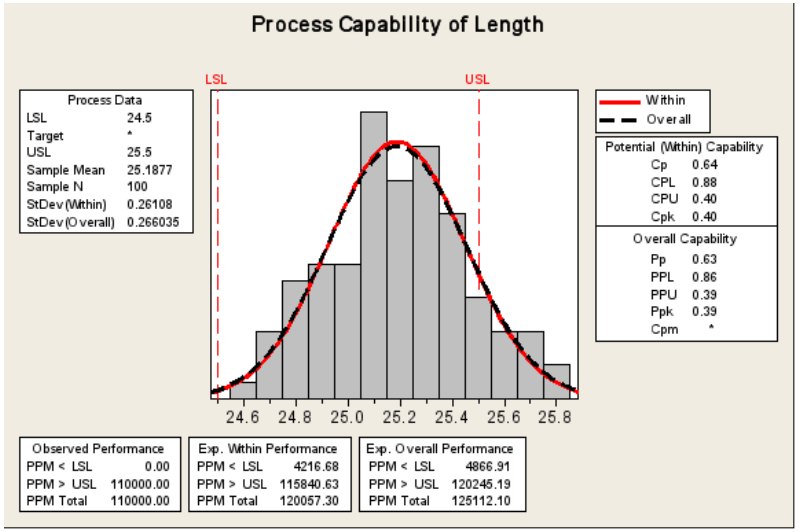
* = The supplier shall retain at appropriate locations, and submit to customer upon request. The customer will identify what is needed for submission base on changes and conditions

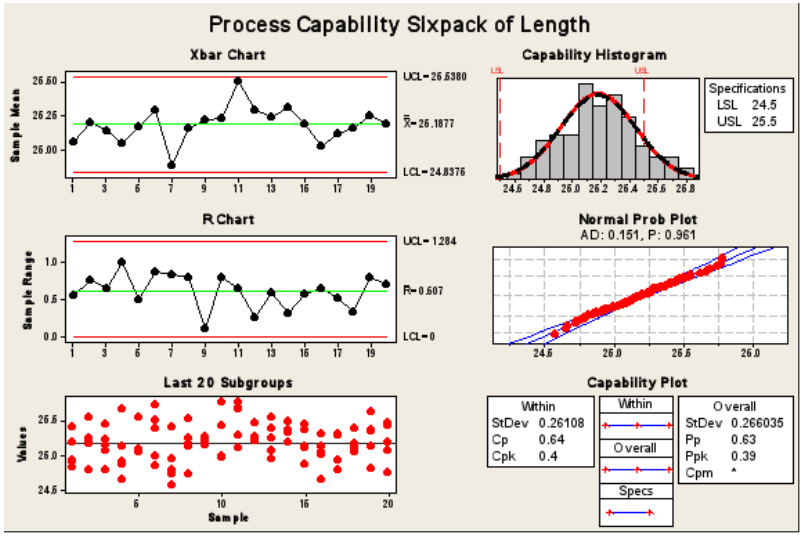
PLEASE CONTACT YOUR SUPPLIER QUALITY ENGINEER WITH ANY QUESTIONS .

Even though Initial Process Study is coded as an "R" on the PPAP Submission Level Table, we felt it was important to provide a brief overview during training

R = Supplier shall retain at appropriate locations, including manufacturing and make readily available to the customer representative upon request

Initial Process Study





What is It?

A set of tools used to understand process capability.

Objective or Purpose

- To evaluate the performance of your process as compared to specification limits
- To determine if the production process is likely to produce product that will meet customer requirements

When to Use It

1. To establish baseline capability.
2. To validate process improvements.

Steps for Determining Process Capability

1. Decide on the product or process characteristic to be assessed
2. Validate the specification limits
3. Validate the measurement system
4. Collect data
5. Assess data characteristics
6. Assess process stability
7. Calculate process capability

Step 1: Which Characteristic

Step 1

Decide on the product or process characteristic to be assessed.

- ***Required* for all critical characteristics**
- ***If no critical characteristics exist, NCR reserves the right to require demonstration of initial process capability on other characteristics***

Step 2: Specification Limits

Validate the specification limits by talking to:

- **Customers, suppliers, controlling agencies**

Why is validation of the specification limits important?

- **They may not represent what the customer truly desires/needs.**
- **May contain "guard banding" as a result of past problems or measurement error.**
- **They may be based on previous designs and no longer be valid.**

Step 3: Measurement System

Validate the measurement system through the appropriate MSA

Why is validation of the Measurement System important?

- **If there is significant error in your measurement system, then decisions are influenced by the error not just the measurements themselves.**

Step 4: Data Collection

When collecting data, consider the following:

- **Short term data**
  - **Free of special causes**
  - **Collected across a narrow inference space i.e. one shift, one machine, one operator, etc..**
- **Long term data**
  - **Subjected to the effects of both random and special cause variation**
  - **Collected across a broad inference space i.e. multiple shifts, machines, operators, etc.**

Step 4: Data Collection

Step 4

When collecting data, consider the following:

- **Rational sub-grouping**
  - **A group of units produced under the same set of conditions**
  - **Mean to represent a "snapshot" of the process**

***Example*:**

A die cut machine produces 100 plastic parts per hour. The quality engineer measures 5 randomly selected parts at the beginning of every hour. Each sample of 5 parts is a subgroup.

- **Between subgroup: variation between subgroups that may be caused by specific identifiable factors, or special causes**
  - **To improve process quality, every effort should be made to eliminate between subgroup variation and reduce within subgroup variation**

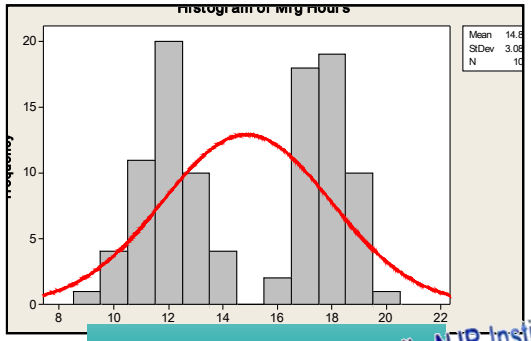
Step 5: Data Characteristics

Step 5

Assess data characteristics

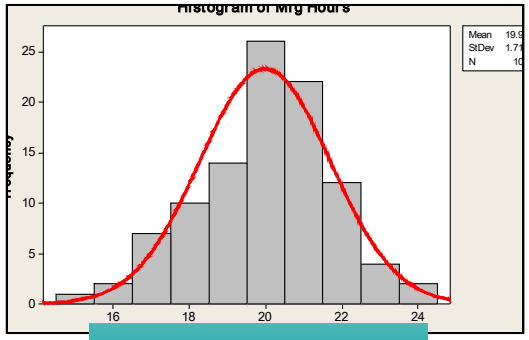
Examine the shape of your data.

- **Is it what you would expect? If not, investigate.**

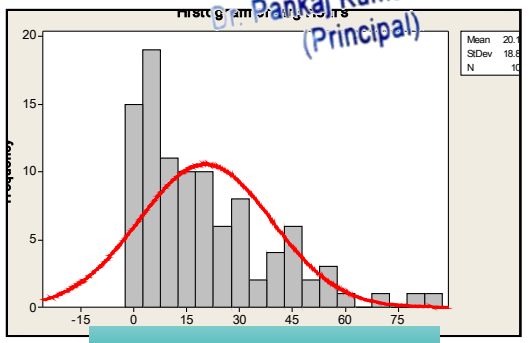


Bimodal Data

The shape of your data is important for determining which type of Capability Analysis applies.



Normal Data



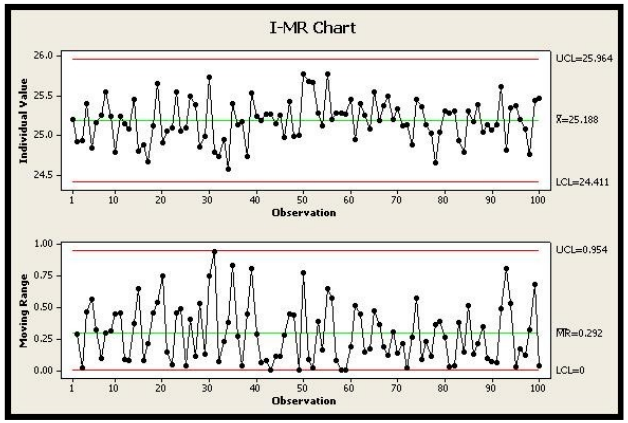
Skewed Data

Step 6: Process Stability

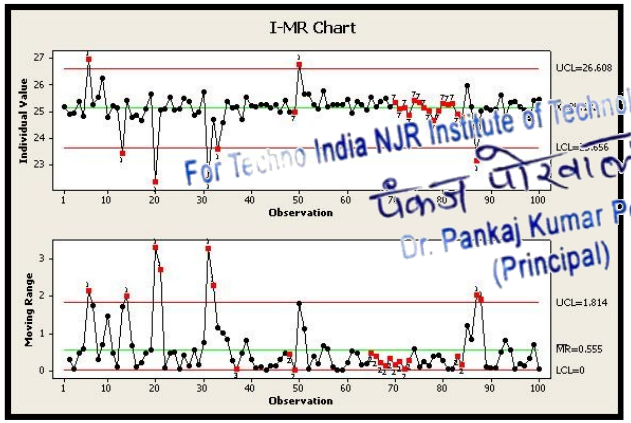
Step 6

Assess process stability in order to understand how your process behaves over time. Control charts are the recommended tool.

Control Chart Examples



Process is stable and in control



Process is not stable and therefore not in control

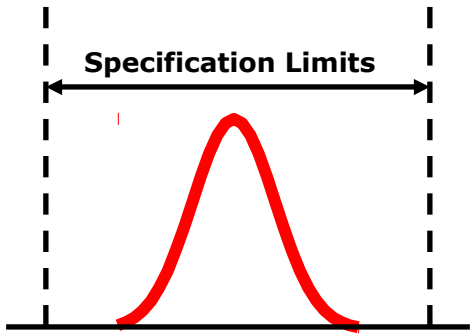
Capability is only valid when the process being studied is stable!

Step 7: Process Capability

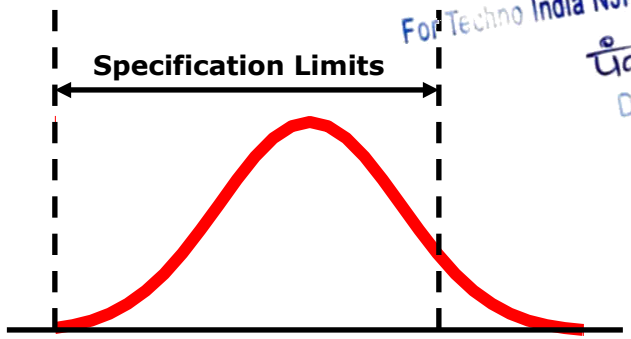
Step 7

Calculate the appropriate statistical metrics in order to determine how the "Voice of the Process" compares to the "Voice of the Customer."

Capability Metrics: PPM, DPMO, Cp, Cpk, Pp, & Ppk ; Sigma Levels (Z Scores)



Process is capable



Process is not capable

If you were driving a truck, and the dotted lines were the construction barriers, what would be happening in each situation?

Focus on Variable Data

The initial process study should be focused on *variable*, not attribute data

- **Assembly errors, test failures, and surface defects are examples of attribute data, which is important to understand, but is not covered in this initial study**
- **To understand the performance of characteristics monitored by attribute data will require more data collected over time**
- **Unless approved by an authorized NCR representative, *attribute data are not acceptable for PPAP submission***

Focus on *variable* data

Capability Indices

Capability Index	Formula	What it shows
C_p	$\frac{(USL - LSL)}{3*s_{short\text{-}term}}$	**Relates short term (within subgroup) standard deviation to tolerance**
C_{pk}	$\frac{(USL - LSL)}{3*s_{short\text{-}term}}$	**called "Entitlement," meaning it is the rent process can do, if centered** **rt term mean & short term (within standard deviation to tolerance** **Only tells you about the nearest spec limit; doesn't tell anything about the other side**
P_P	$\frac{(USL - LSL)}{3*s_{long\text{-}term}}$	**Relates long term (overall) standard deviation to**
P_{pk}	$\frac{(USL - LSL)}{3*s_{long\text{-}term}}$	**n & long term (overall) standard tolerance** **Only tells you about the nearest spec limit; doesn't tell anything about the other side**

Cp/Cpk are used to *estimate* potential process *capability*

Pp/Ppk are used to *measure* actual process *performance*

Capability Indices - Cpk

Cpk *predicts capability*

- Based on short term within subgroup variation
- Does not include the effect of process variability between subgroups

Cpk should be used when:

- Developing new parts
- Revising specifications on a part
- Materials, processes, manufacturing location, or equipment have significantly changed
- Material suppliers have changed (include certificate of analysis)

Capability Indices - Ppk

Ppk indicates *past performance*

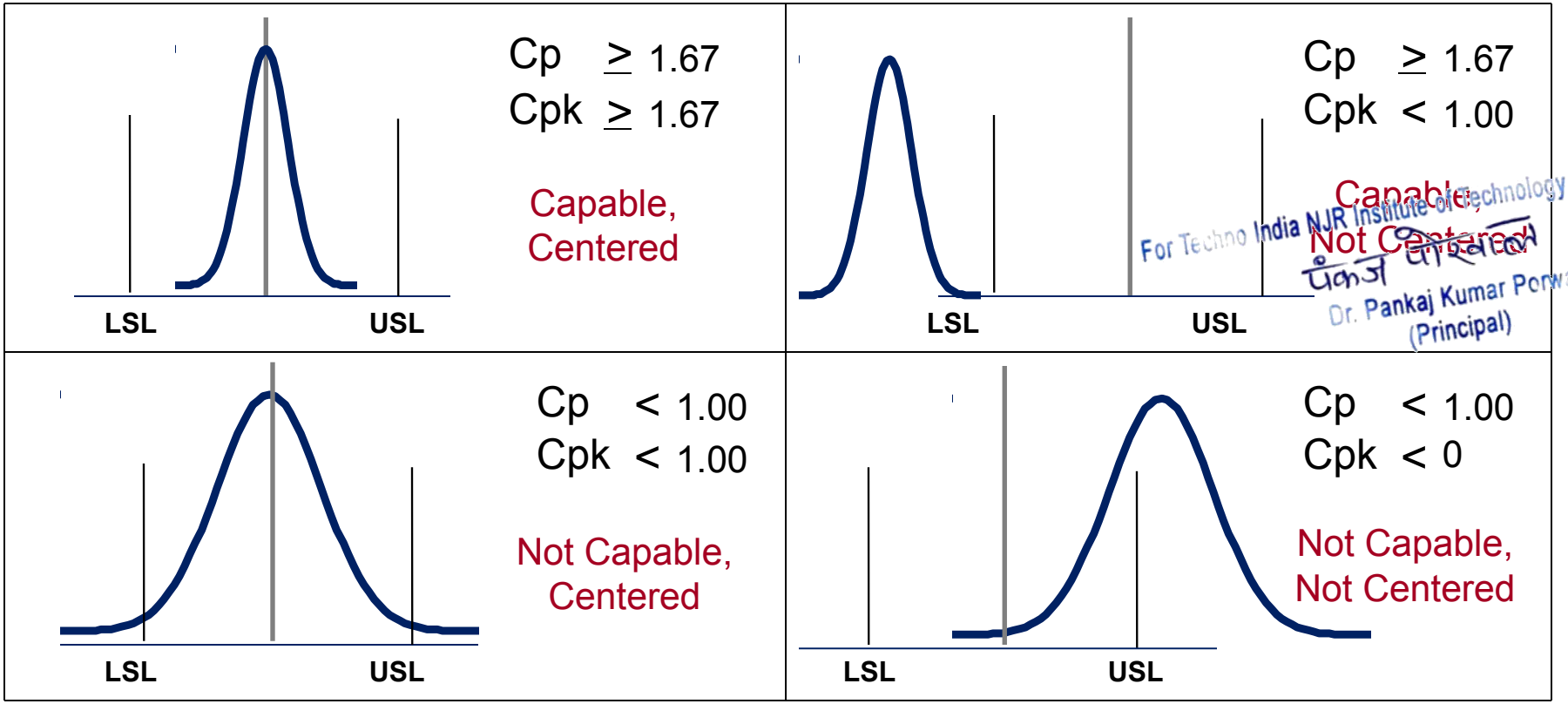
- Based on long term total variation
- Unlike Cpk, Ppk is not limited to variation within subgroups
- However, Ppk cannot isolate within subgroup variation from between subgroup variation
- When calculated from the same data set, Cpk and Ppk can be compared to analyze the sources of process variation

Ppk should be used when:

- The supplier is new to NCR, but has already been manufacturing a part
- The supplier is existing, but has produced a number of nonconforming parts

Difference between Cp & Cpk

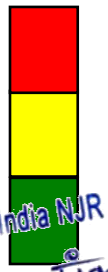
- **Cp** – determines capability of producing to specification
- **Cpk** – same as Cp, but also measures how *centered* the process is
- It is important to look at both!



Acceptance Criteria

Acceptance criteria for critical vs. non-critical characteristics

	Critical	Non-Critical	Decision
Red (Bad)	<1.33	<1.00	
Yellow (OK)	1.33-1.67	1.00-1.33	
Green (Good)	>1.67	>1.33	



Cpk must be greater than or equal to 1.67 for *critical* processes

Cpk must be greater than or equal to 1.33 for *non-critical* processes

Initial Process Study

Reviewer's Checklist

- ✓ **Ensure that the results are acceptable, and that the process is stable and capable of producing a quality part**
- ✓ **PPAPs should only be approved if the capability is greater than 1.67 for critical dimensions and greater than 1.33 for non-critical dimensions**
- ✓ **More information about capability is available in the Appendix at the end of this presentation**

QUALIFIED LABORATORY DOCUMENTATION

Qualified Laboratory Documentation

- **Inspection and testing for PPAP shall be performed by a qualified laboratory as defined by NCR requirements (e.g., an accredited laboratory).**
- **The qualified laboratory (internal or external to the supplier) shall have a laboratory scope and documentation showing that the laboratory is qualified for the type of measurements or tests conducted.**
  - **When an external laboratory is used, the supplier shall submit the test results on the laboratory letterhead or the normal laboratory report format**
  - **The name of the laboratory that performed the tests, the date(s) of the tests, and the standards used to run the tests shall be identified.**

APPEARANCE APPROVAL REPORT

Appearance Approval Report

Appearance Approval Report

Part Number	Drawing Number	Application	
Part Name	Buyer	E/C Level	Date
Supplier Name	Manufacturing Location		Supplier Code
Reason for Submission: ☐ Part Submission Warrant ☐ Special Sample ☐ Re-Submission ☐ Pre Texture ☐ First Production Shipment ☐ Engineering Change			Other

Appearance Evaluation

Supplier Sourcing and Texture Information		Pre-Texture Evaluation	Customer Representative signature and Date
		Correct and Proceed	
		Correct and Resubmit	
		Approved to Texture	

Color Evaluation

Color Suffix	Tristimulus Data					Master Number	Master Date	Material Type	Material Source	Hue				Value		Chroma		Gloss		Metallic Brilliance		Color Shipping Suffix	Part Disposition
	DL*	Da*	Db*	DE	CMC					Red	Yel	Grn	Blu	Light	Dark	Gray	Clear	High	Low	High	Low		

Comments:

Supplier Signature	Phone No.	Date	Customer Representative Signature	Date

What is It?

- A report completed by the supplier containing appearance and color criteria

Objective or Purpose

- To demonstrate that the part has met the appearance requirements on the design record

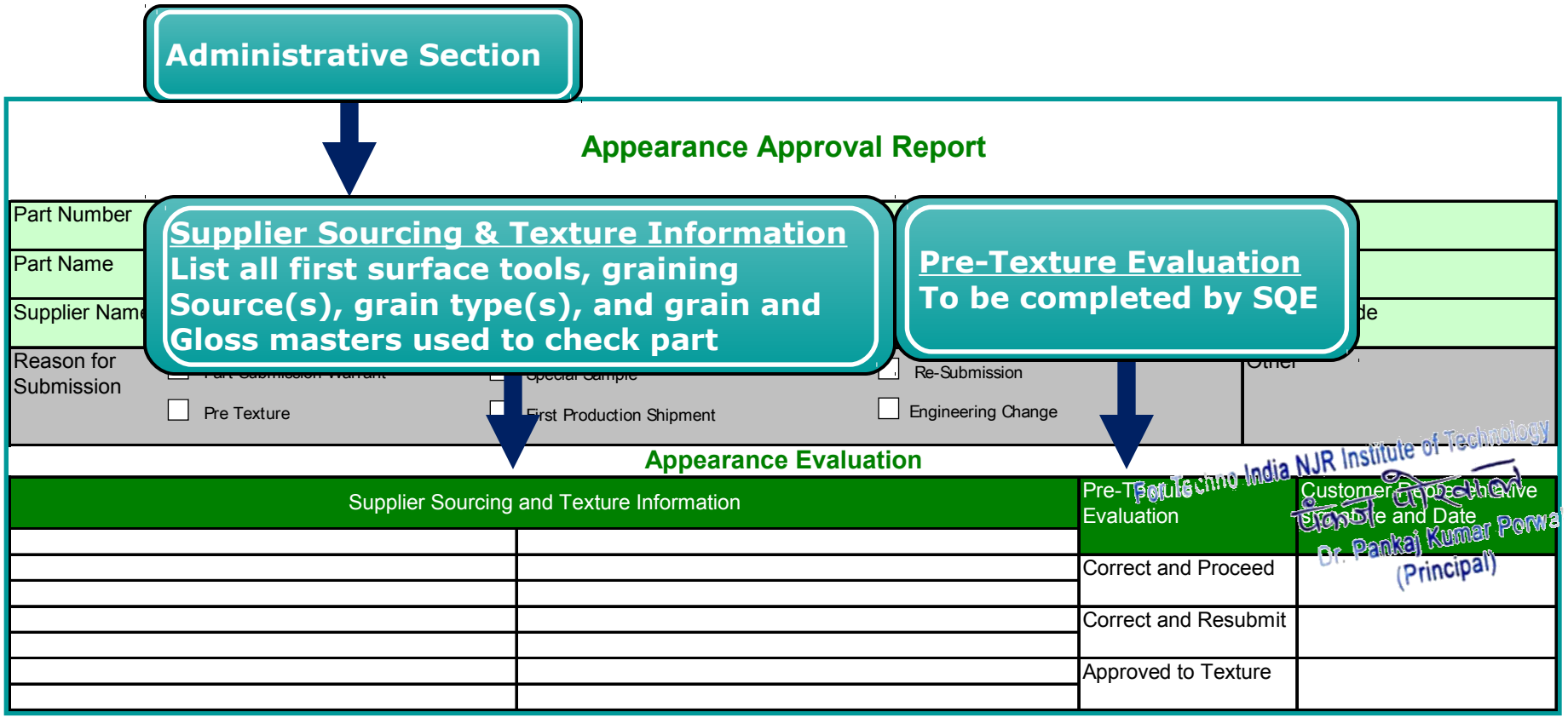
When to Use It

- Prior to tooling for production

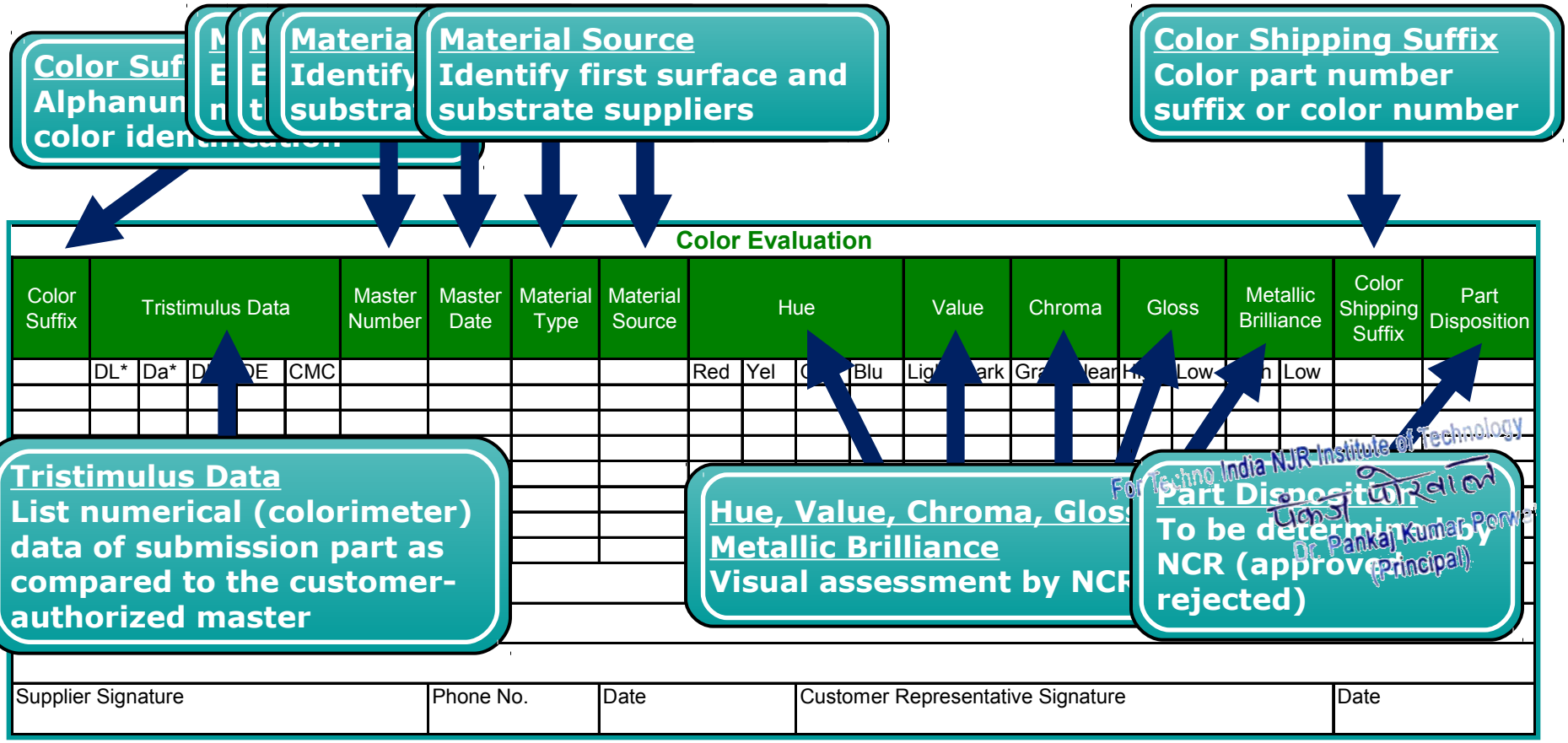
IMPORTANT!

Typically only applies for parts with color, grain, or surface appearance requirements

Appearance Approval Report

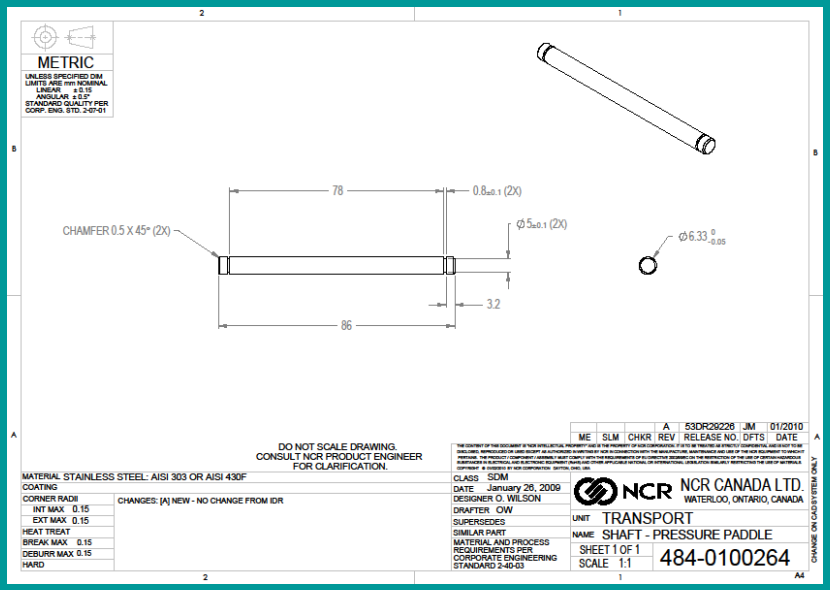


Appearance Approval Report



SAMPLE PRODUCTION PARTS

Sample Production Parts



What is It?

Actual samples that reflect the parts documented in the PPAP.

Objective or Purpose

- Confirm cosmetic or functional part approval.

When to Use It

- Sample parts should be delivered WITH the PPAP submission

Sample Production Parts

- **The sample parts provided should be the same parts measured for the dimensional results**
- **Default quantity for all submissions is 3 parts unless otherwise requested**

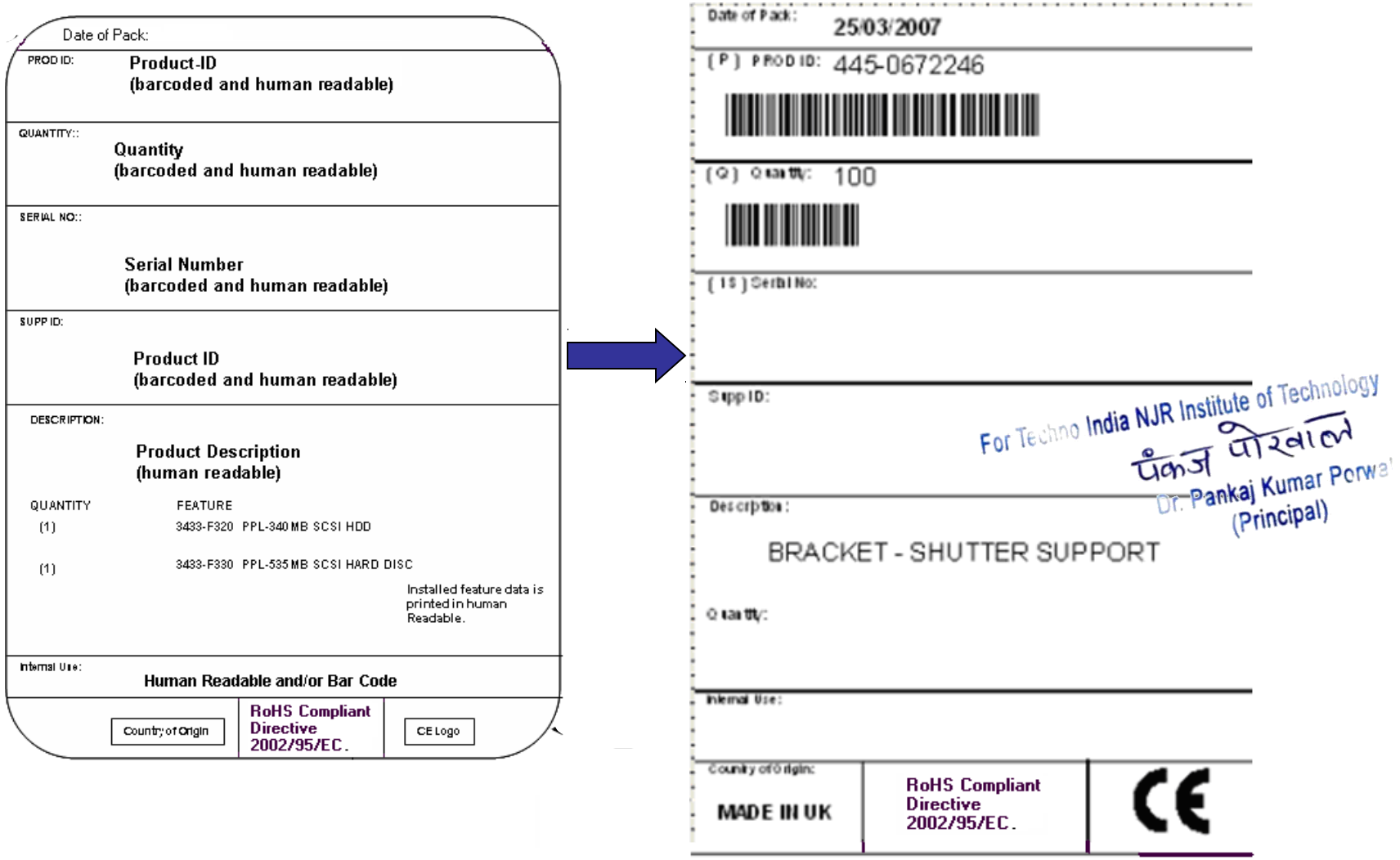
Sample Production Parts

Sample production parts MUST be properly identified

- Include the following information on the part label:
  - Date parts were packed
  - NCR part number
  - Quantity
  - Serial number
  - Supplier part number (optional)
  - Part description
  - Country of origin
  - Indication of RoHS compliance
  - Approval markings (UL, CE, etc.) where applicable

See NCR part label examples on the next slide

Part Label Example



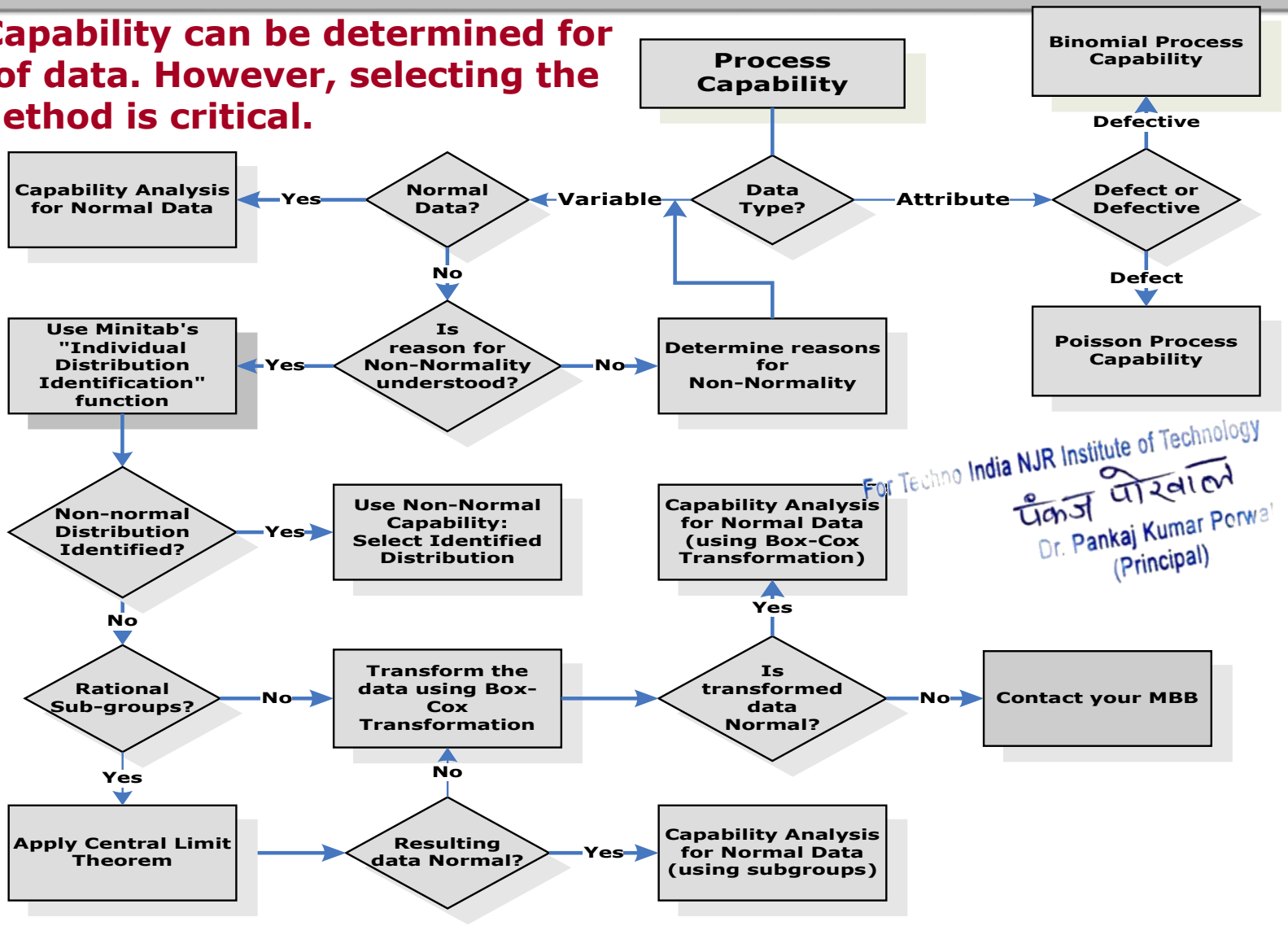
PPAP Summary

- **The Production Part Approval Process is an extensive approval process for *new or changed* designs or processes**
- **It is very formalized, so it inevitably causes some administrative work**
- **Later changes to the product or process can be expensive and time-consuming!**

APPENDIX – CAPABILITY

Process Capability Tool Selection Map

Process Capability can be determined for all types of data. However, selecting the correct method is critical.



Index of Capability Examples (Using Minitab)

Capability – Normal

- Capability - Normal

Capability – Non-Normal

- Distribution Identification
- Central Limit Theorem
- Box – Cox Transformation

Normal Capability Example

Activity

Using the data in a Minitab file Capability Example.MTW determine the capability of the PO process in terms of the time is required to process the POs.

	Indiv Dates_1	Time to Process
	10-Apr	19.7
	10-Apr	23.2
	10-Apr	34.3
	10-Apr	27.8
	10-Apr	29.9
	11-Apr	38.8
	11-Apr	37.4
	11-Apr	42.4
	11-Apr	34.9

Time to Process one individual PO

Use the file **Capability Example.MTW**

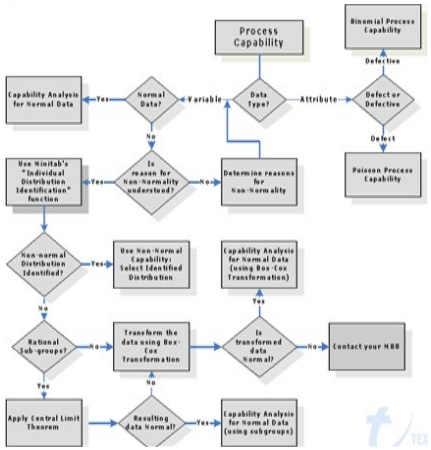
Normal Capability Example

Q **Which Capability Analysis applies?**

Is the data attribute or variable?

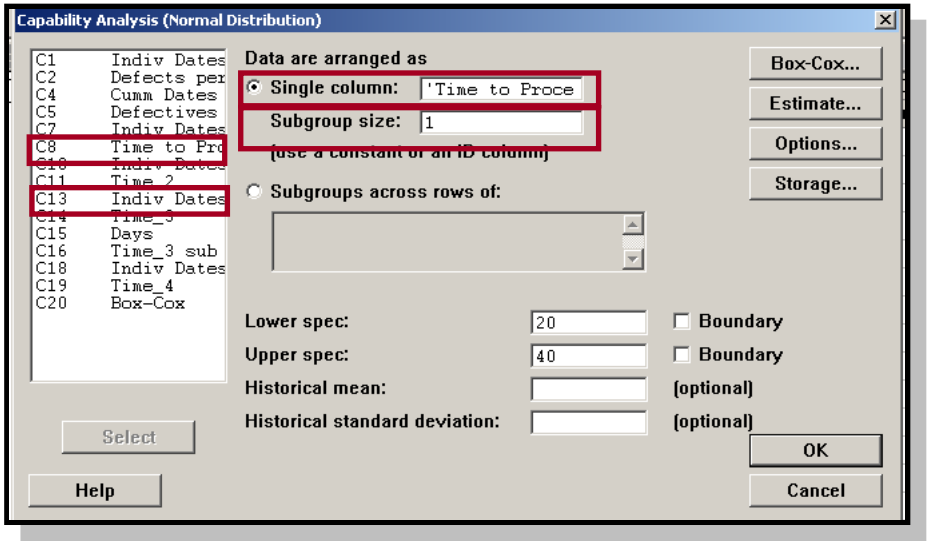
Is the data normal? **Yes**

Does sub-grouping apply? **???**



A **Normal**

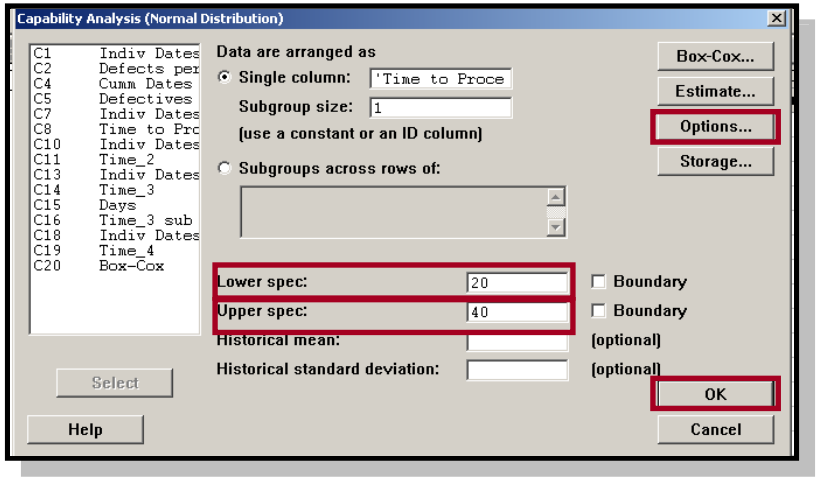
Normal Capability Analysis in Minitab

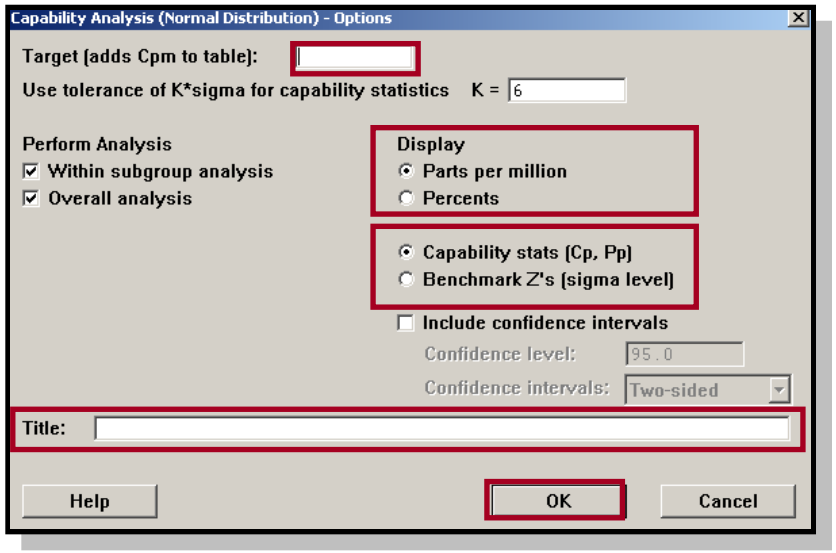


1. Open the worksheet **Capability Example.MTW**.
2. Choose **Stat > Quality Tools > Capability Analysis > Normal**.
3. Click in the **[Single Column]** field.
4. Double click **[Time to Process]** in the column on the left.
5. Click in the **[Subgroup Size]** field.
6. Depending on subgroup information either:
   a. Enter 1 if the subgroup size is 1.
   b. Double click **Indiv Dates_1** in the column on the left.
   c. Since the subgroup size is constant (n=5) the number 5 could be typed in the subgroup size field.

Use the file **Capability Example MTW**

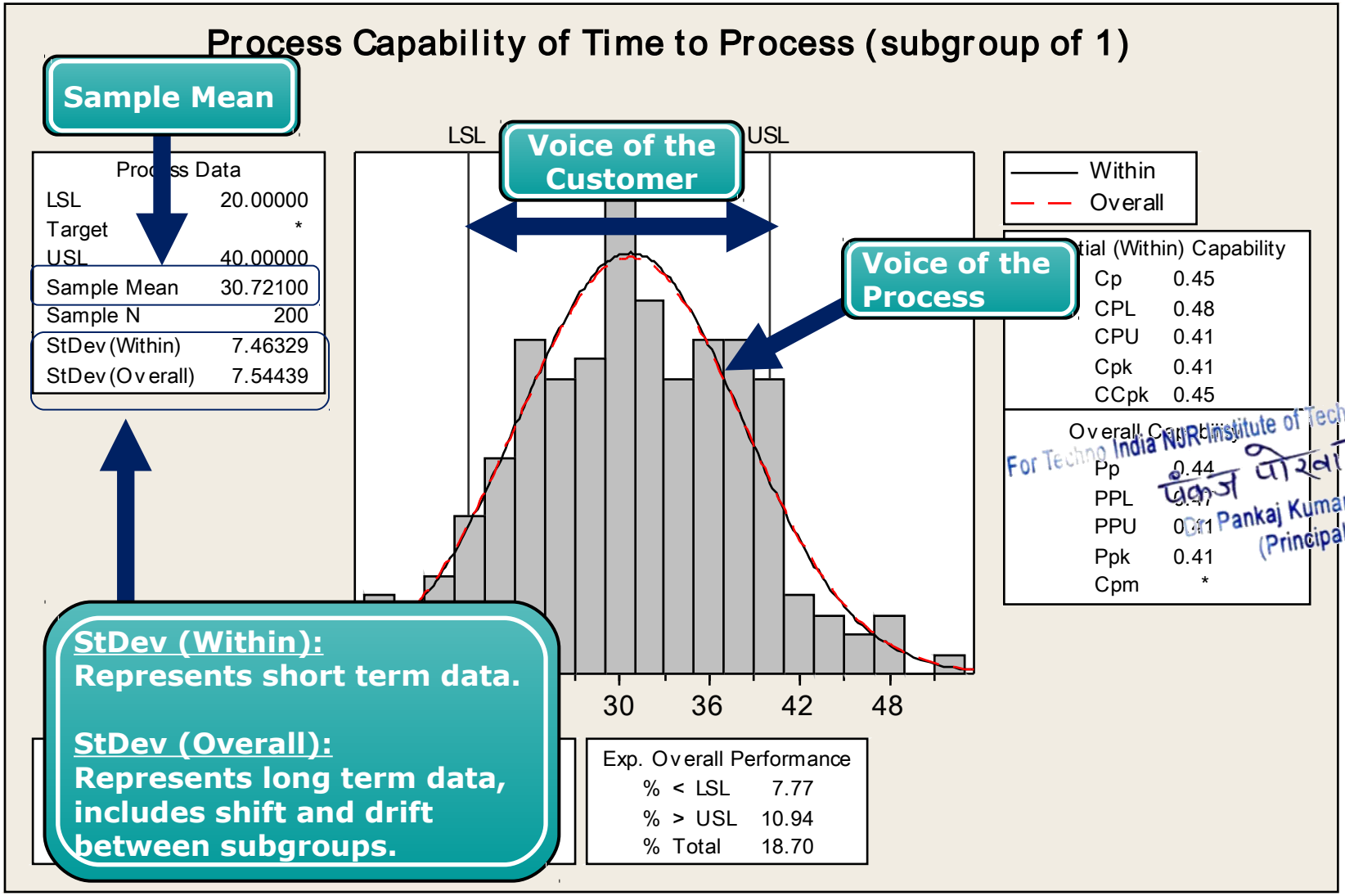
Normal Capability Analysis in Minitab



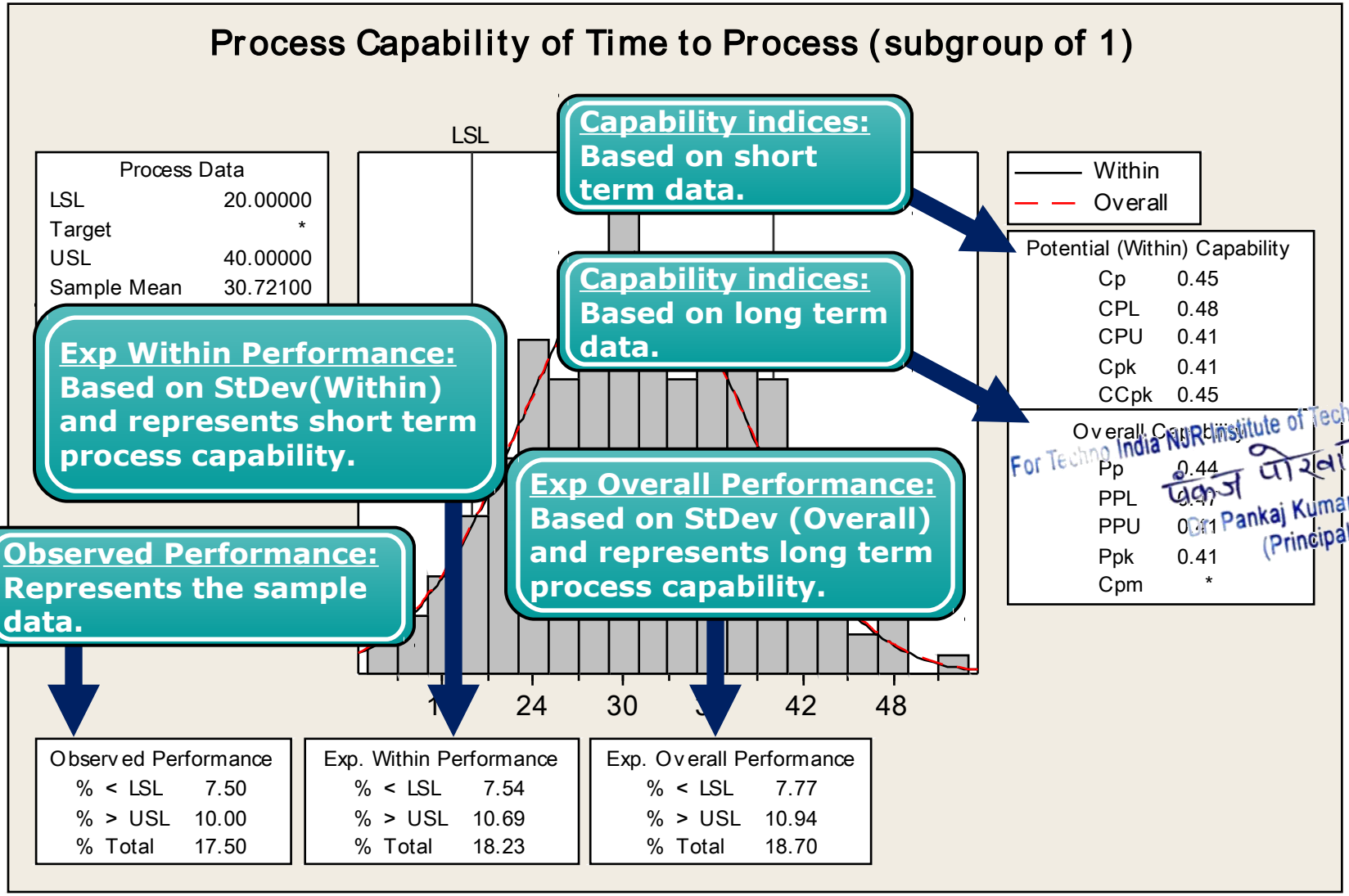


7. **Type 20 in Lower Spec.**
8. **Type 40 in Upper Spec.**
9. **Select [Options] button.**
10. **Add target value (if applicable).**
11. **Under Display select**
    a. **Parts per million or Percents**
    b. **Capability Stats or Benchmark Z**
7. **Add Title if desired.**
8. **Click [OK].**
9. **Click [OK].**

Normal Capability Analysis Results



Normal Capability Analysis Results



Non-Normal Capability – Distribution Identification

Exercise

Using the data (Time_2) in a Minitab file Capability Example.MTW determine the capability of the PO process in terms of the time that is required to process the POs.

	Indiv Dates_2	Time_2	
	3-Apr	27.2	
	3-Apr	29.8	
	3-Apr	35.1	
	3-Apr	49.9	
	3-Apr	25.5	
	4-Apr	26.6	
	4-Apr	36.4	
	4-Apr	41.9	
	4-Apr	26.1	

Time to Process one individual PO

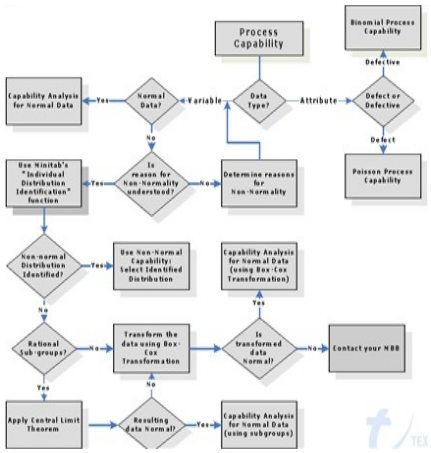
Use the file **Capability Example. MTW**

Non-Normal Capability – Distribution Identification

Q

Which Capability Analysis applies?

- **Is the data attribute or variable?**
- **Is the data normal?** **No**
- **Are the reasons for non-normality understood?** **Yes**
- **Can the data be described by another distribution?** **???**

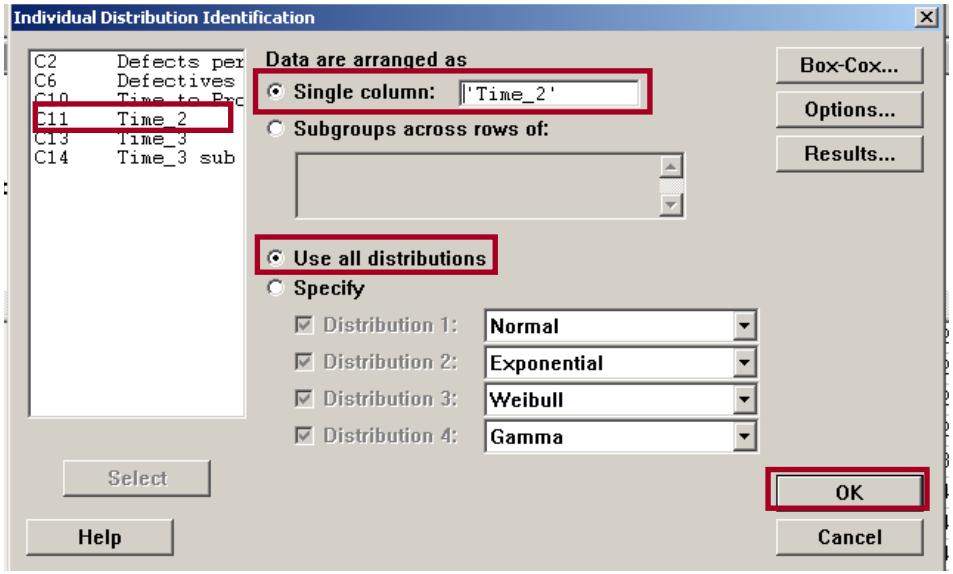


A

Non-normal

Try Individual Distribution Identification

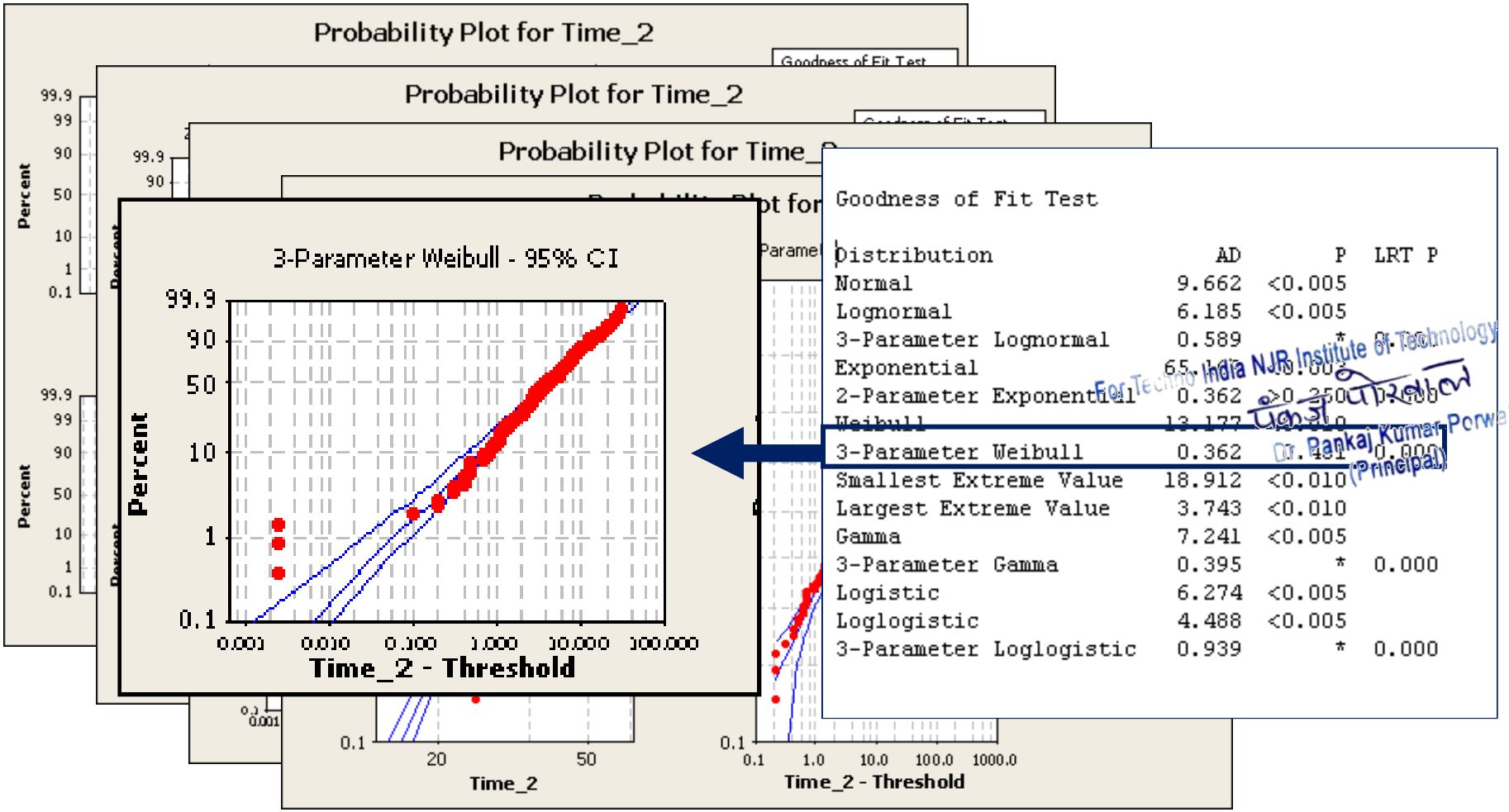
Individual Distribution Identification in Minitab



1. Open the worksheet **Capability Example.MTW**.
2. Choose **Stat** > **Quality Tools** > **Individual Distribution Identification**.
3. Click in the **[Single Column]** field.
4. Double click **Time_2** in the column on the left.
5. Choose **[Use all distributions]**.
6. Click **[OK]**.

Use the file **Capability Example. MTW**

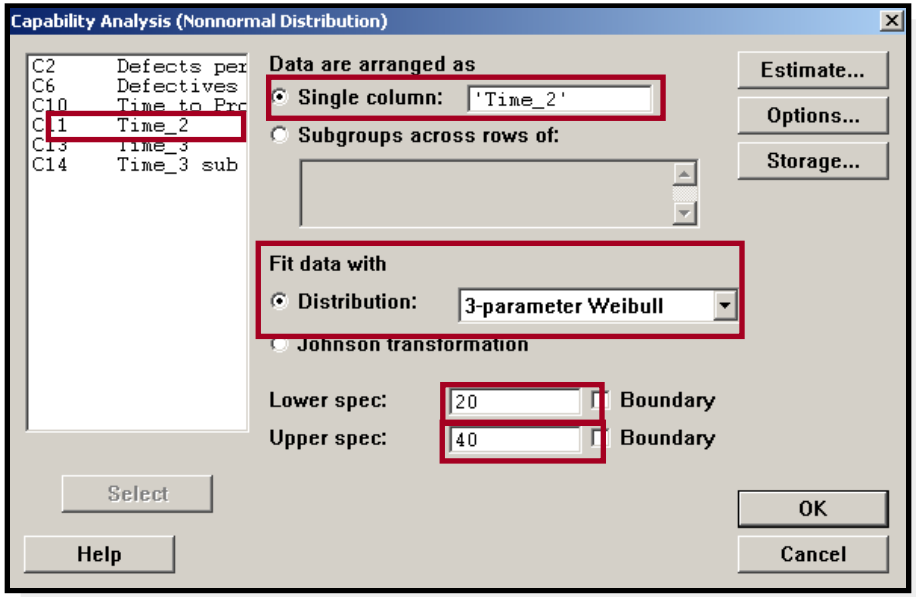
Individual Distribution Identification in Minitab



Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	9.662	<0.005	
Lognormal	6.185	<0.005	
3-Parameter Lognormal	0.589	*	
Exponential	65.[illegible]	[illegible]	
2-Parameter Exponential	0.362	>0.250	0.000
Weibull	13.177	<0.010	
3-Parameter Weibull	0.362	0.481	0.000
Smallest Extreme Value	18.912	<0.010	
Largest Extreme Value	3.743	<0.010	
Gamma	7.241	<0.005	
3-Parameter Gamma	0.395	*	0.000
Logistic	6.274	<0.005	
Loglogistic	4.488	<0.005	
3-Parameter Loglogistic	0.939	*	0.000

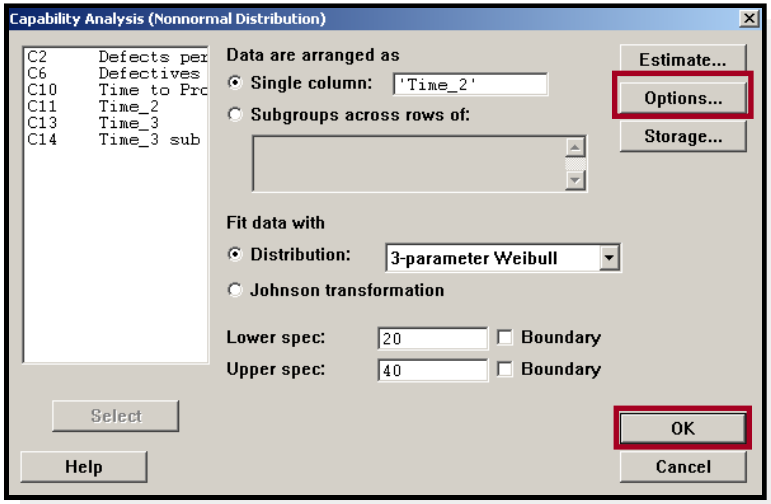
Using Individual Distribution Identification

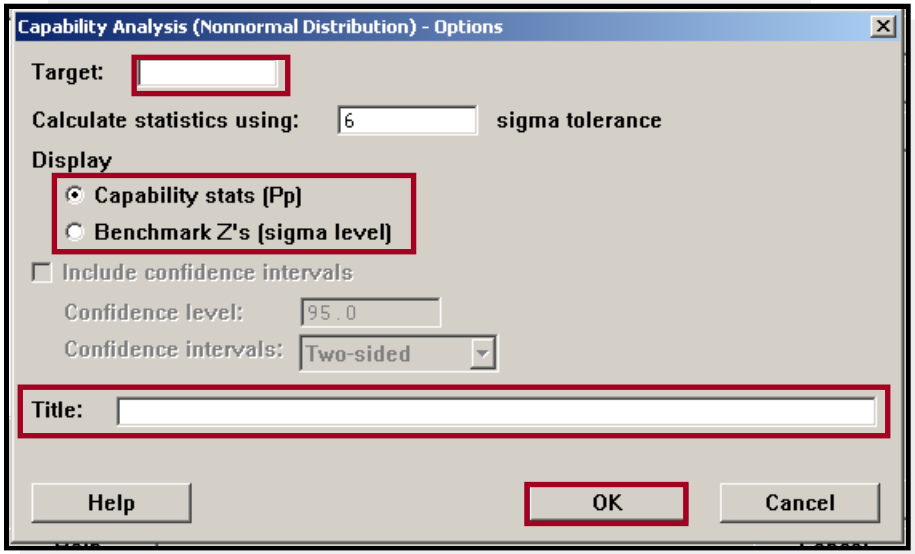


1. Open the worksheet **Capability Example.MTW**.
2. Choose **Stat > Quality Tools > Capability Analysis > Nonnormal**.
3. Click in the **[Single Column]** field.
4. Double click **Time_2** in the column on the left.
5. Select **[Fit data with Distribution]**.
6. Using pulldown menu select **[3-parameter Weibull]**.
7. Type 20 in **[Lower Spec]**.
8. Type 40 in **[Upper Spec]**.

Use the file **Capability Example. MTW**

Using Individual Distribution Identification

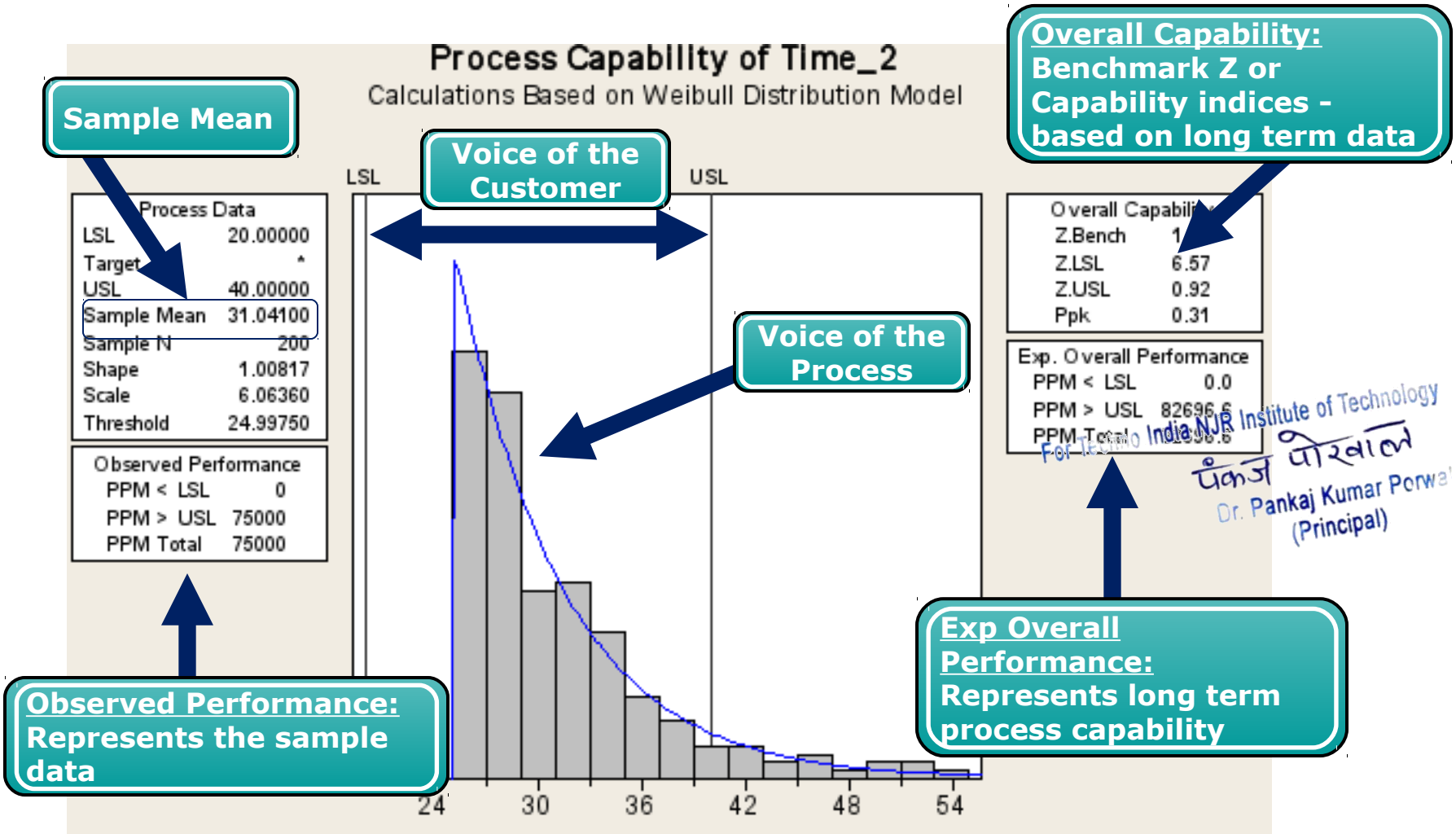




9. Select [Options] button.
10. Add target value (if applicable).
11. Under Display select
    1. Capability Stats
    2. Benchmark Z
12. Add Title if desired.
13. Click [OK].
14. Click [OK].

For Techno India NJR Institute of Technology
पंकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

Using Individual Distribution Identification



Non-Normal Capability – Central Limit Theorem

Activity

Using the data (Time_3 and Time 3 sub) in a Minitab file Capability Example.MTW determine the capability of the PO process in terms of the time is required to process the POs.

	C13-D	C14	C15-D	C16
	Indiv Dates_3	Time_3	Days	Time_3 sub
1	1-Apr	38.3	1-Apr	38.66
2	1-Apr	42.7	2-Apr	25.10
3	1-Apr	32.0	3-Apr	42.78
4	1-Apr	50.4	4-Apr	26.58
5	1-Apr	29.9	5-Apr	31.86
6	2-Apr	18.7	8-Apr	35.66
7	2-Apr	29.9	9-Apr	43.00
8	2-Apr	21.5	10-Apr	31.86

Average time to process five POs per day

Time to process one individual PO

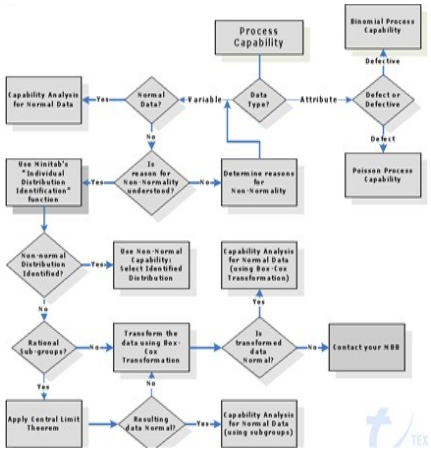
Use the file **Capability Example. MTW**

Non-Normal Capability – Central Limit Theorem

Q

Which Capability Analysis applies?

- **Is the data attribute or variable?**
- **Is the data normal?** **No**
- **Are the reasons for non-normality understood?** **Yes**
- **Can the data be described by another distribution?** **No**
- **Can the data be sub-grouped?** **Yes**
- **Is the sub-grouped data normal?** **???**

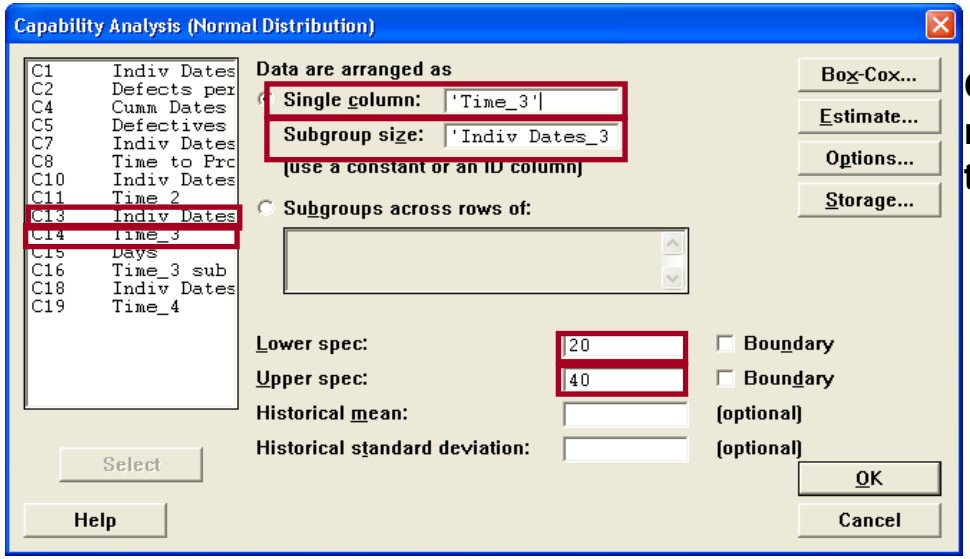


A

Non-normal

Try sub-grouping the data

Using Central Limit Theorem Sub-Grouping



Caution!

Check sub-group data Time_3 sub for normality. If the data is not normal then this method cannot be used!

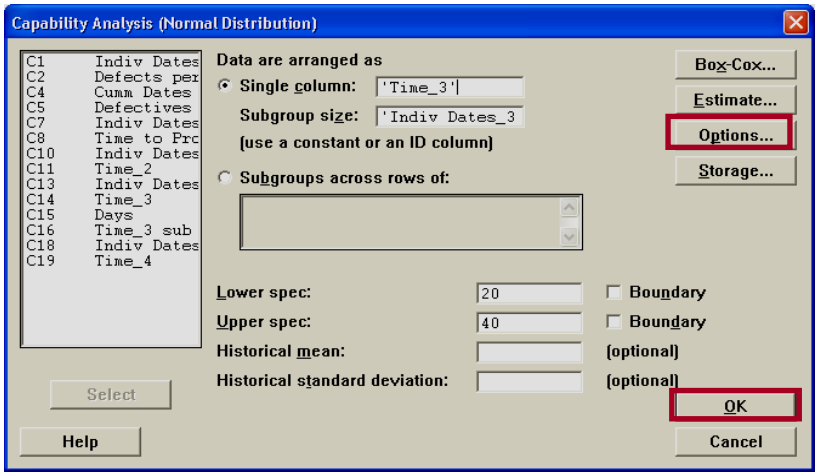
1. **Open the worksheet Capability Example.MTW.**
2. **Choose Stat > Quality Tools > Capability Analysis > Normal.**
3. **Click in the [Single Column] field.**
4. **Double click Time_3 in the column on the left.**
5. **Click in the [Subgroup Size] field – Double click Individ Dates_3 in the column on the left.**
6. **Type 20 in [Lower Spec].**
7. **Type 40 in [Upper Spec].**

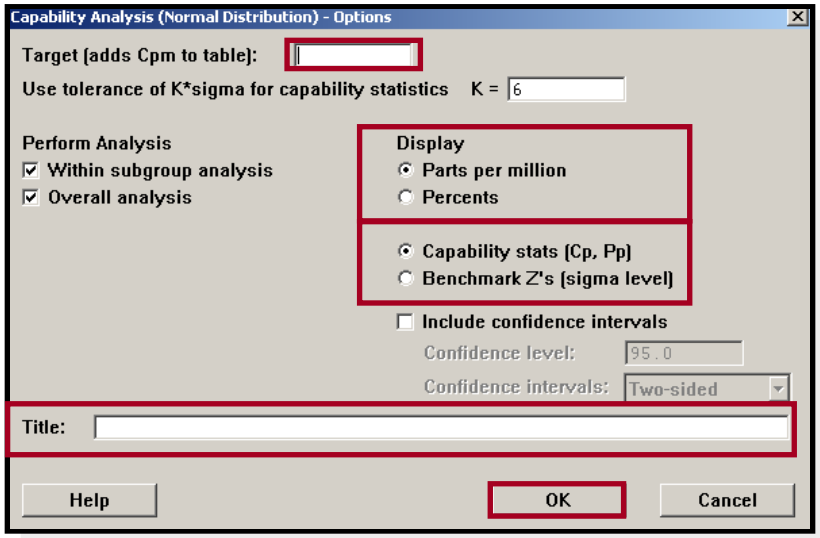
Important!

The sub-groups have to make logical sense, such as by day, by shift, by machine…

Use the file **Capability Example. MTW**

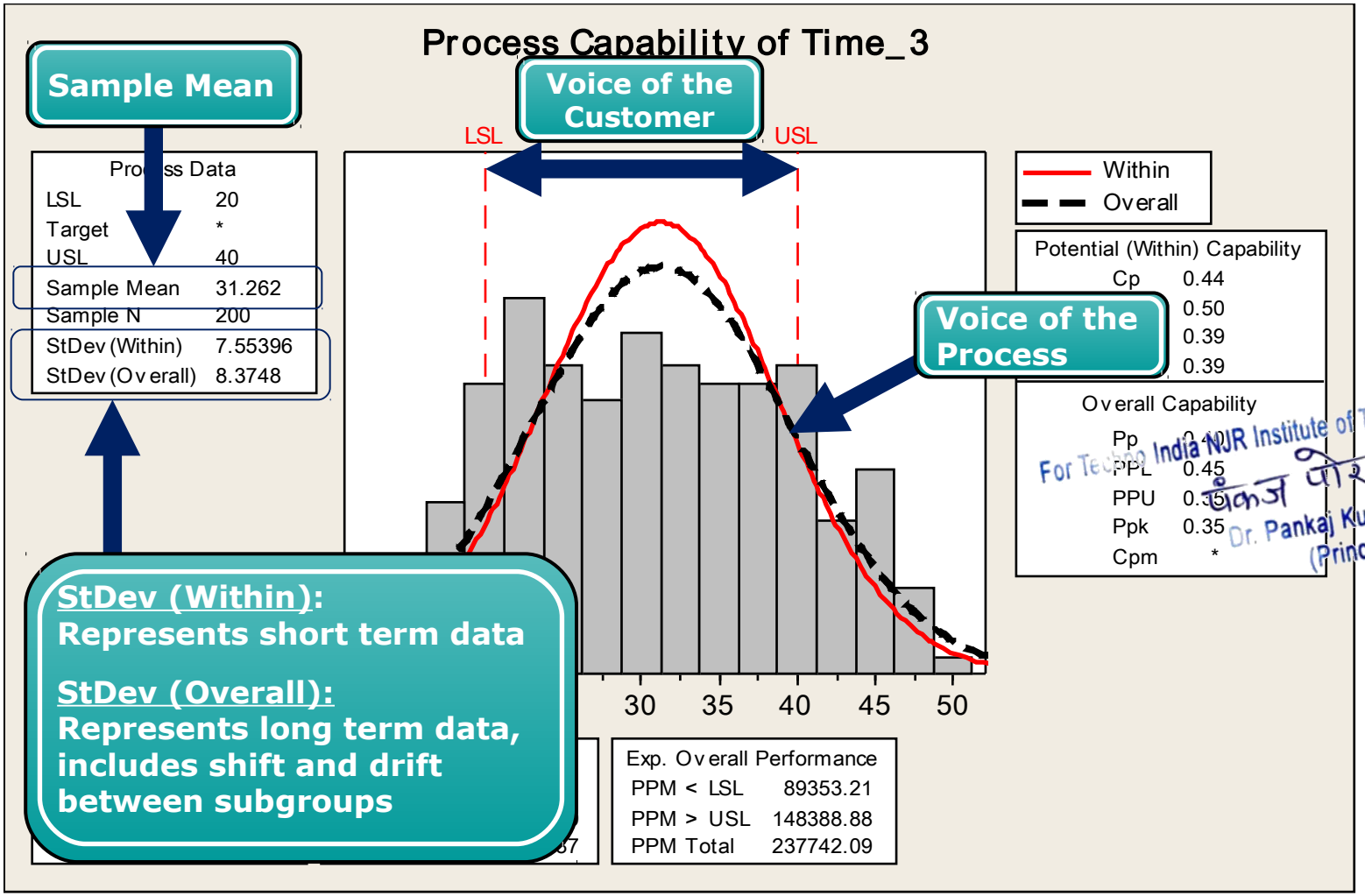
Using Central Limit Theorem Sub-Grouping



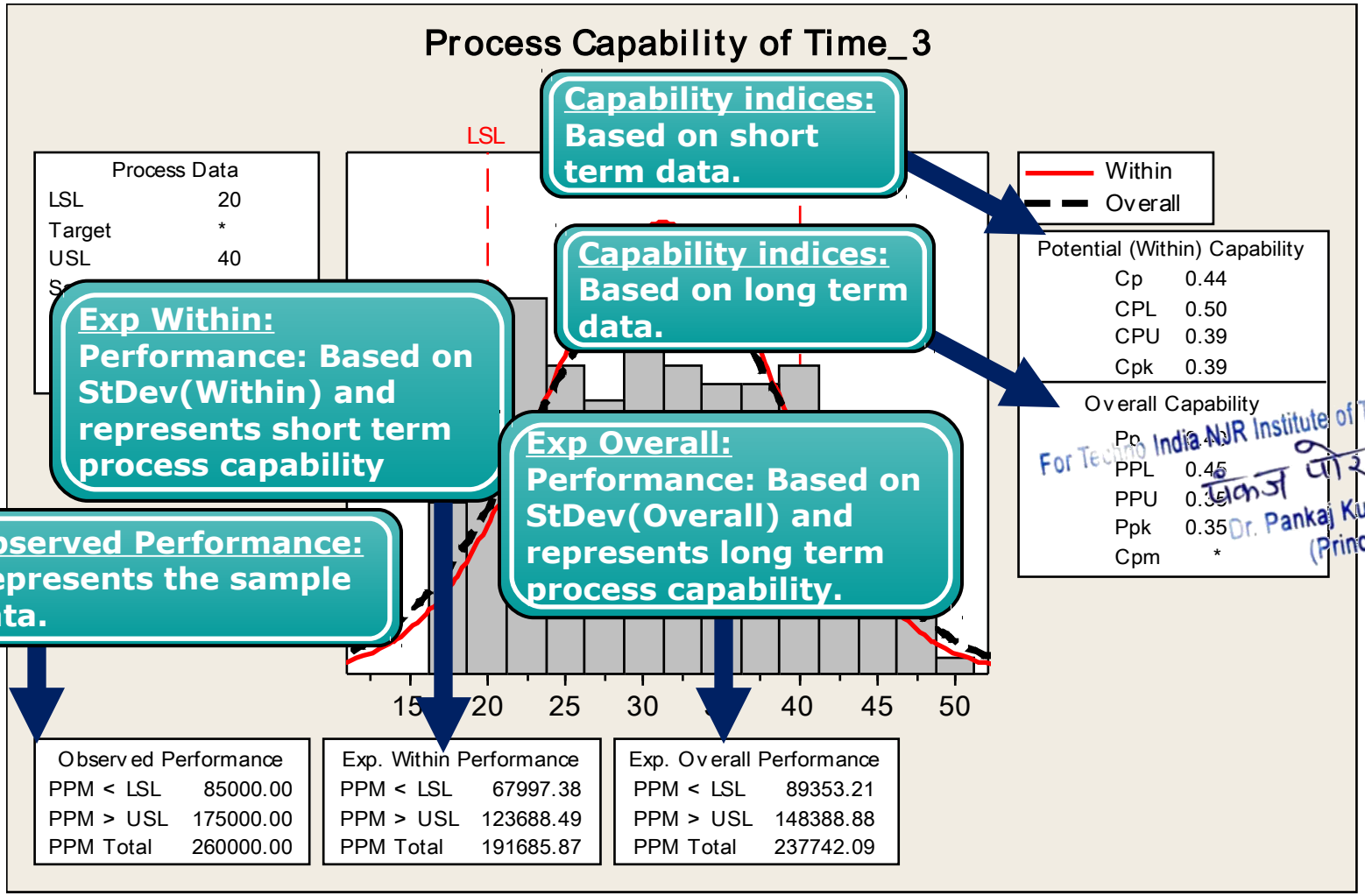


8. **Select [Options] button.**
9. **Add target value (if applicable).**
10. **Under Display select**
    1. **Parts per million or Percents**
    2. **Capability Stats or Benchmark Z**
11. **Add Title if desired.**
12. **Click [OK].**
13. **Click [OK].**

Using Central Limit Theorem Sub-Grouping



Using Central Limit Theorem Sub-Grouping



Non-Normal Capability – Box-Cox Transformation

Activity

Using the data (Time_4) in a Minitab file Capability Example.MTW determine the capability of the PO process in terms of the time is required to process the POs.

	Indiv Dates_4	Time_4	
	2-Apr	17.4	
	2-Apr	59.0	
	2-Apr	10.4	
	3-Apr	7.2	
	3-Apr	13.8	
	3-Apr	29.5	
	3-Apr	45.5	
	3-Apr	103.9	
	4-Apr	12.2	
	4-Apr	49.7	

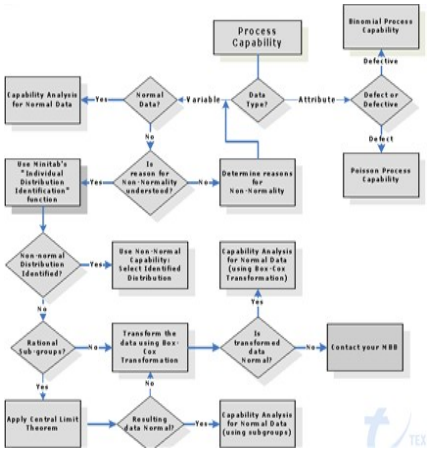
Time to Process one individual PO

Non-Normal Capability – Box-Cox Transformation

Q

Which Capability Analysis applies?

- **Is the data attribute or variable?**
- **Is the data normal?** **No**
- **Are the reasons for non-normality understood?** **Yes**
- **Can the data be described by another distribution?** **No**
- **Can the data be sub-grouped?** **No**
- **Can data be transformed?** **???**

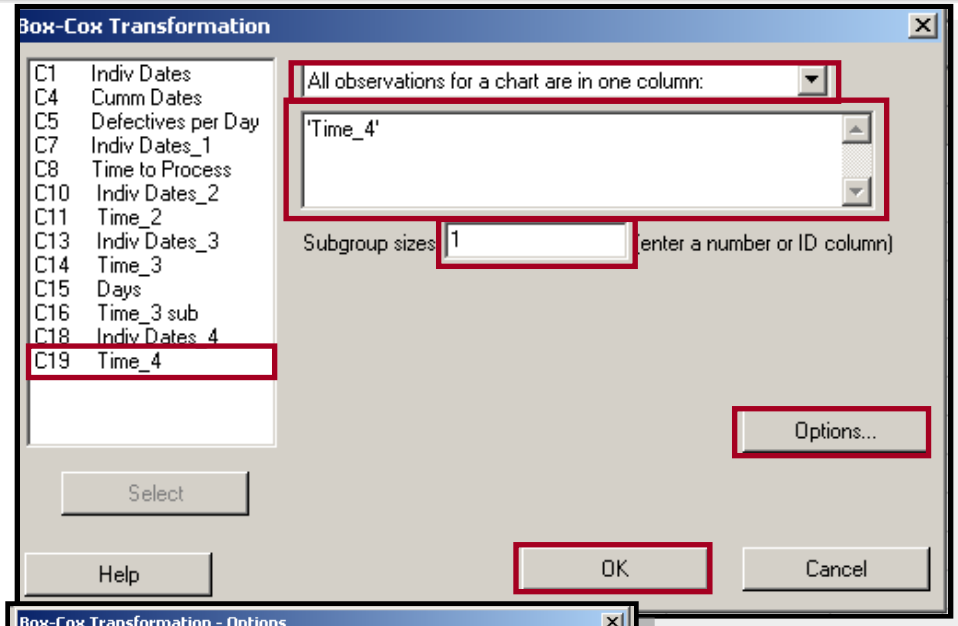


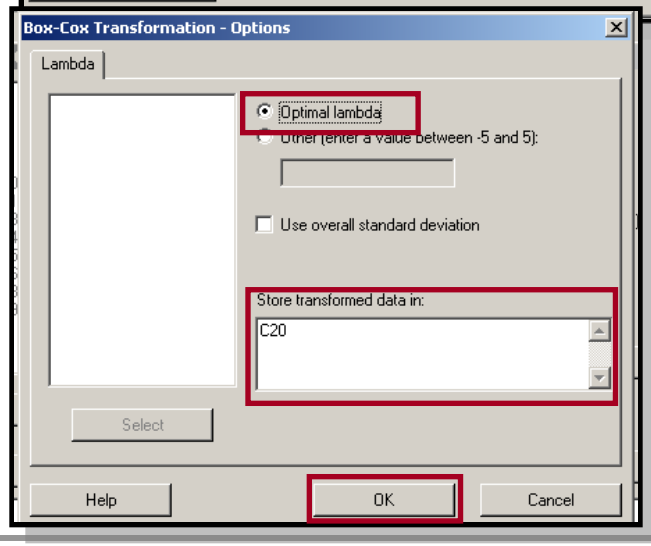
A

Non-normal

Try Box-Cox transformation

Box-Cox Transformation



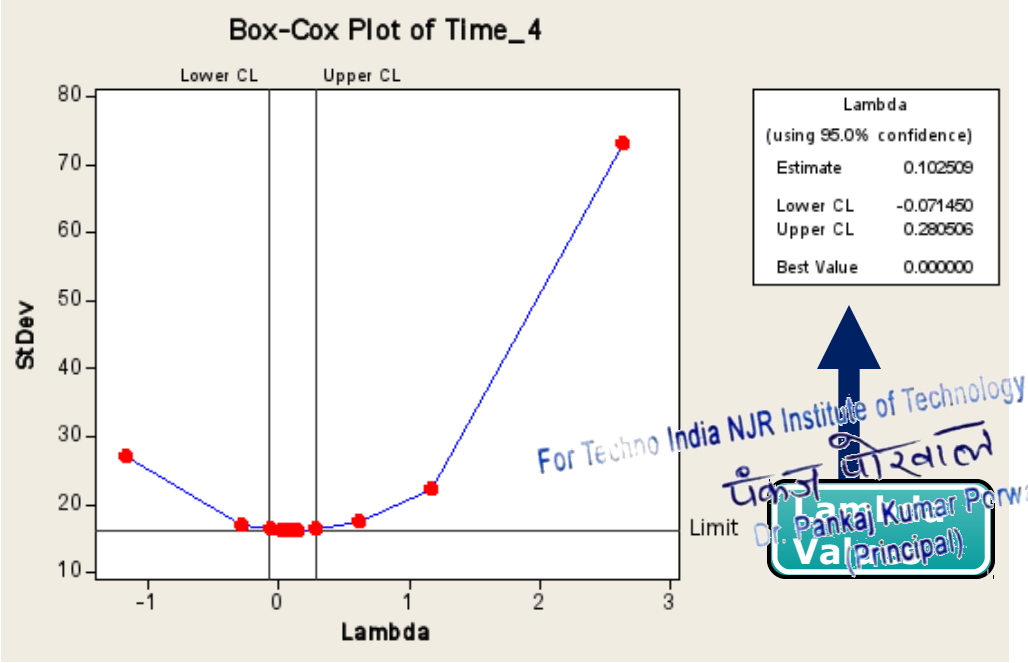


1. Open the worksheet **Capability Example.MTW**
2. Choose **Stat > Control Charts > Box-Cox Transformation**
3. Choose **[All Observations …in one column]** from pull down menu
4. Click in Large Box
5. Double click **[Time_4]** in the column on the left
6. Click in the **[Subgroup Size]** field, enter 1
7. Select **[Options]** radio button
8. Select **[Optimal Lambda]**
9. Enter column for Stored Data
10. Click **[OK]**
11. Click **[OK]**

Box-Cox Transformation Results

7	C18-D	C19	C20	
	Indiv Dates_4	Time_4	Box-Cox	
	2-Apr	17.4	2.85647	
	2-Apr	[illegible]	4.07754	
	2-Apr	10.4	2.34181	
	[illegible]pr	7.2	1.97408	
	[illegible]	[illegible]8	2.62467	
	[illegible]	[illegible]5	3.38439	
	3-Apr	45.5	3.81771	
	3-Apr	103.9	4.64343	
	4-Apr	12.2	2.50144	

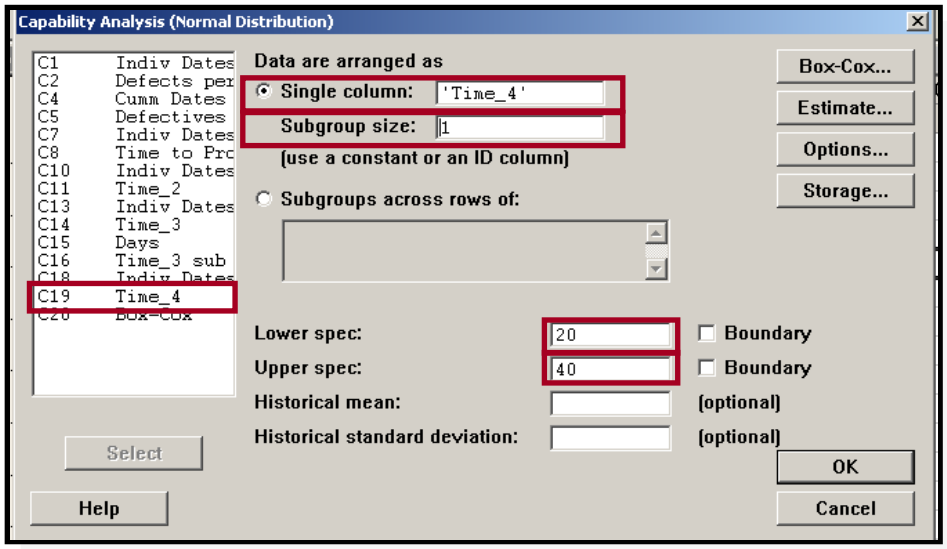
Transformed Data



Lambda Value

Q Is the transformed data normal?

Using Box-Cox Transformation



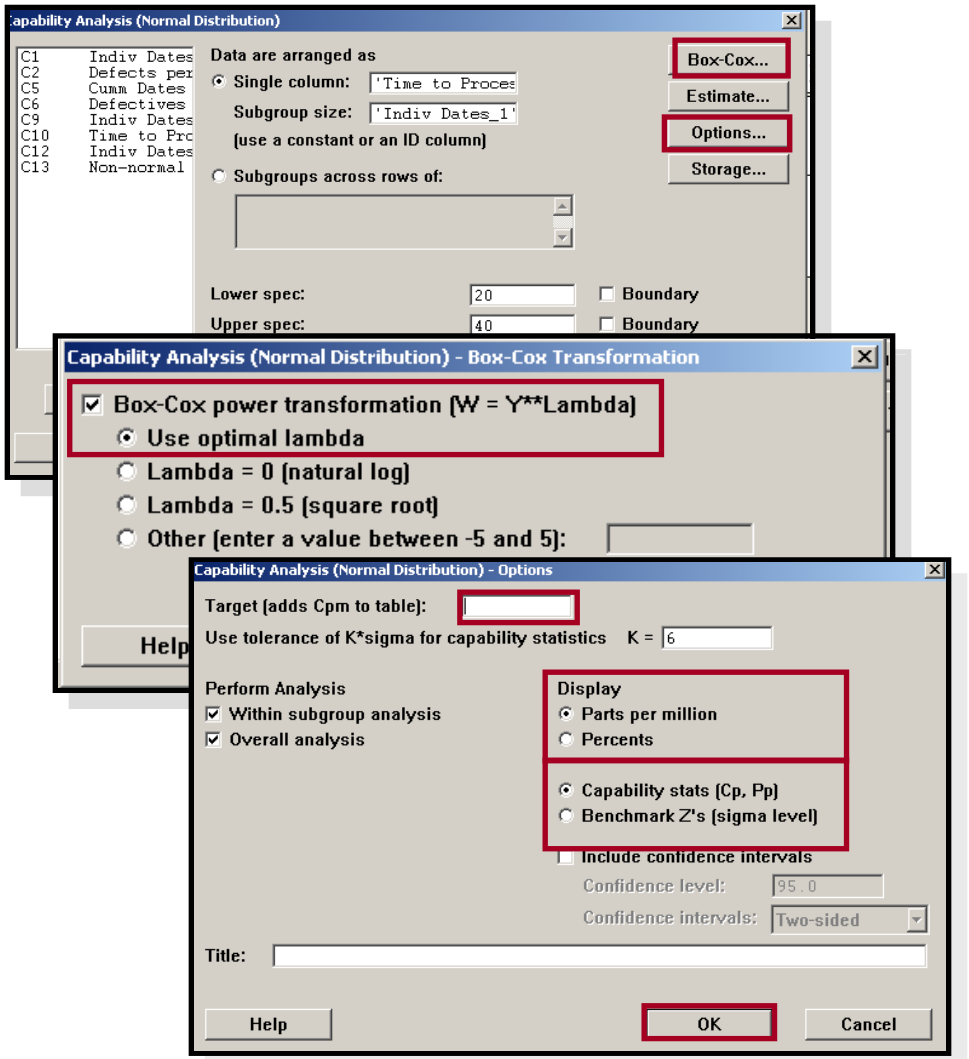
1. Open the worksheet **Capability Example.MTW**
2. Choose **Stat > Quality Tools > Capability Analysis > Normal**
3. Click in the **[Single Column]** field
4. Double click **Time_4** in the column on the left
   - Use the original data, not the transformed data.
1. Click in the **[Subgroup Size]** field – enter 1 (the data is already sub-grouped)
2. Type 20 in Lower Spec
3. Type 40 in Upper Spec

Caution!

Check transformed data for normality. If the data is not normal then this method cannot be used!

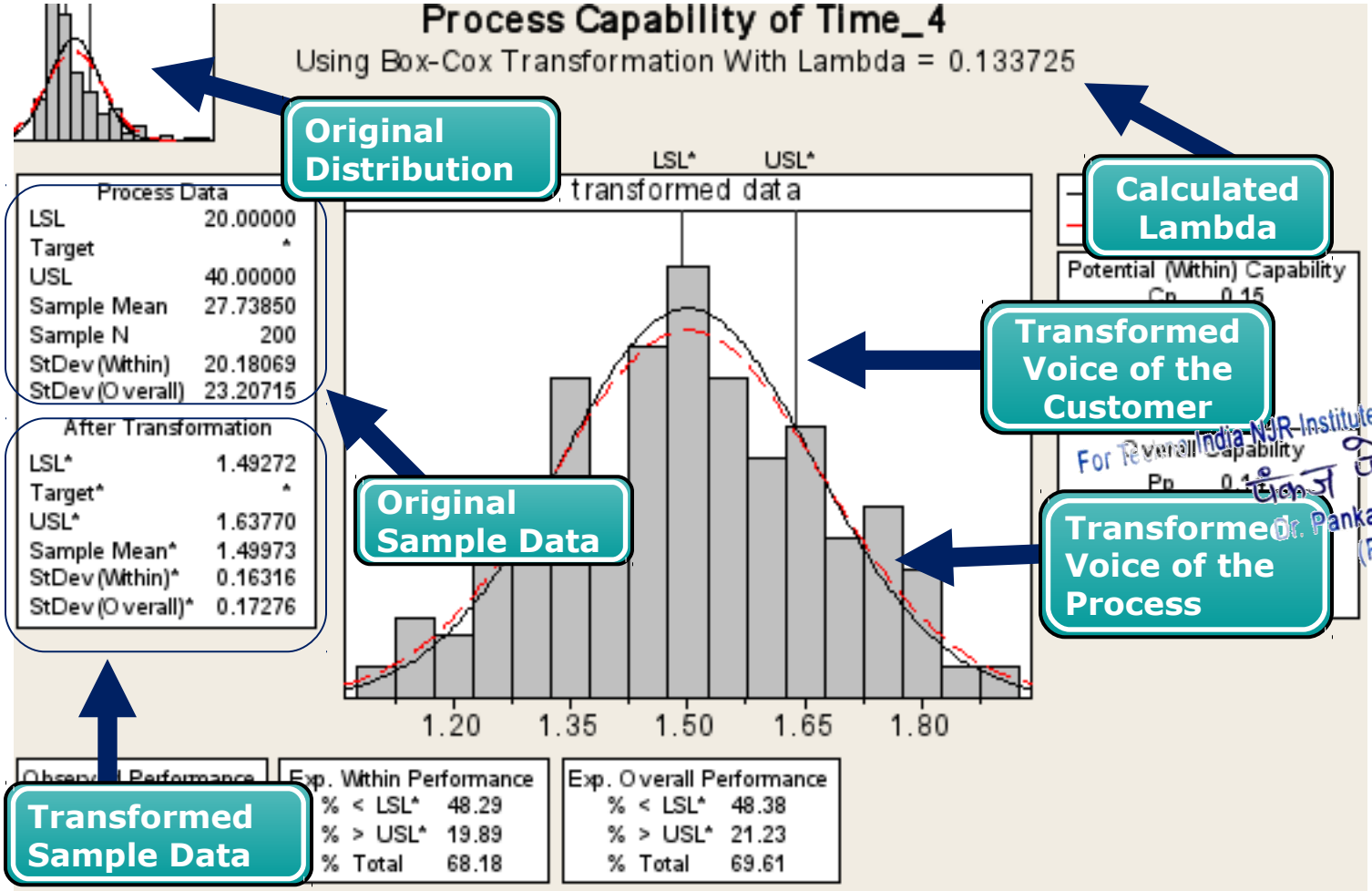
Use the file **Capability Example. MTW**

Using Box-Cox Transformation



1. Select [Box-Cox] radio button
2. Select [Box-Cox power transformation]
3. Select [Use Optional lambda]
4. Click OK
5. Select [Options] radio button
6. Add target value (if applicable)
7. Under Display select
   a. Parts per million or Percents
   b. Capability Stats or Benchmark Z
8. Add Title if desired
9. Click [OK]
10. Click [OK]

Using Box-Cox Transformation



Using Box-Cox Transformation