THE POWER OF PRECONTROL

Tools & Tips Webinar sponsored by the AESQ Process Control Methods SMIG

April 11, 2023

The Power of PreControl
Agenda – 60 minutes

Overview – S. Hampton

Who is the PCM Subject Matter Interest Group

Why this webinar? Where can we find help?

PCM Community of Practice – Linked In

PreControl Walk Through – A. Stout

Case Studies

Q&A – PCM SMIG Team

Summary and Close – S. Hampton

Andrew Stout
MBB, +
Pratt & Whitney Canada

Steve Hampton
Process Control Manager
LPC-T, PCC Structurals

WEBINAR OVERVIEW

We are **recording** today's webinar and will distribute the video link following the close of the webinar. It will also be posted on the AESQ website for free viewing.

We will take **questions** during today's webinar using the **Chat** feature.

Please remain on Mute during the presentation to prevent background noise. We will also be muting all lines at the start of the session.

The Power of Pre-Control

Why this webinar?

Gain an understanding of how Pre-Control works.
Discuss advantages and disadvantages.

Show practical applications and examples.

Generate thought about using alternate methods.

Promote the available free documents and tools that can be used by any AESQ supplier.

Answer questions.

PROCESS CONTROL METHODS PER RM13006

Purpose of this reference manual

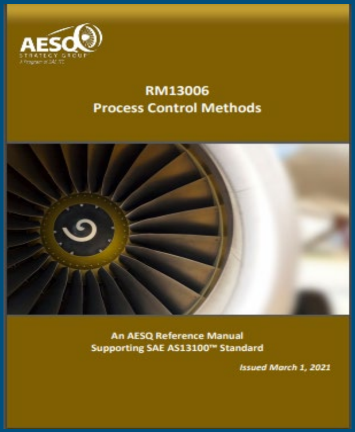
AESQ STRATEGY GROUP
A Program of SAE ITC

RM13006 provides the user with an array of practical approaches to process control used to ensure consistent product quality.

The purpose of this reference manual is to raise the overall capability of the aerospace engine supply chain, standardize the process control requirements across AESQ suppliers, and build on the requirements for process control methods (ref. RM13006).

This reference manual was developed by a dedicated team from AESQ member companies with expert knowledge and experience in the areas of process control, process improvement, quality systems, and supplier engagement.


AEROSPACE STANDARD
AS13100™
Issued 2021-03
AESQ Quality Management System Requirements for Aero Engine Design and Production Organizations
RATIONALE
FOREWORD



PROCESS CONTROL METHODS SUPPORT

What is the Process Control Methods SMIG Group?

- The purpose of the PCM Subject Matter Interest Group is to promote the effective deployment of the process control methods across the AESQ Supply Chain.
- The Group is made up of Subject Matter Experts from the AESQ Member Companies.
- The Group is accountable for the AS13100 related Requirements and associated Reference Manual content, ensuring that it is up to date and reflects current knowledge and best practice.
- It shall promote the effective deployment of the Reference Manual using Communities of Practice (CoP). The CoP is open to any subject matter expert or individual experienced or trained in process control from the aero engine community.
- Activities may include webinars, best practice sharing, development of shared training materials, conferences and published papers.

NO.	FUTURE WEBINAR TOPICS	TARGET DATE/TIME
1	Process Control Methods - What is RM13006? Interaction with other AESQ Reference Manuals	12/6/2022 (completed)
2	What makes a good Process Capability Study?	1/26/2023 (completed)
3	Process Capability Study for True Position (handling MMC)	2/8/2023 (completed)
4	The use of non-statistically based process control methods	3/8/2023 (completed)
5	The Power of Precontrol	4/11/2023 (11 AM U.S. Eastern)
6	The One-Hour Process Control Assessment	5/16/2023 (11 AM U.S. Eastern)
7	Why is statistical control a prerequisite for process capability?	Target 2nd Qtr (June)
8	Dealing with Non-Normal Data	Target 3rd Qtr (September)
9	Conducting capability studies for one-sided geometric tolerances	Target 4th Qtr (October)
	Go to https://aesq.sae-itc.com/events for webinar schedule	

https://aesq.sae-itc.com/interest-groups

SUBJECT MATTER INTEREST GROUPS

Who is the Process Control Methods SMIG Team?

Pete Teti
PWA
(Leader)

Andrew
Stout
PWC
(Co-Lead)

Nicklas
Godebu
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Paul Gorg
PCC

Rudi
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Karen
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Steve
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PCC

Ricardo
Banuelas
Rolls Royce

Grant
Braun
PCC

Marnie
Ham
GE

Shailesh
Shinde
RR

Eric
Prather
GE

Curator for RM13006

Experts who you may address process control related question to

Provider of process control related webinars. See Slide 6 for webinar schedule which is subject to change based on your feedback

PROCESS CONTROL METHODS CoP

Where to get help

AESQ Supplementary Materials webpage for a copy of RM13006 and supporting templates

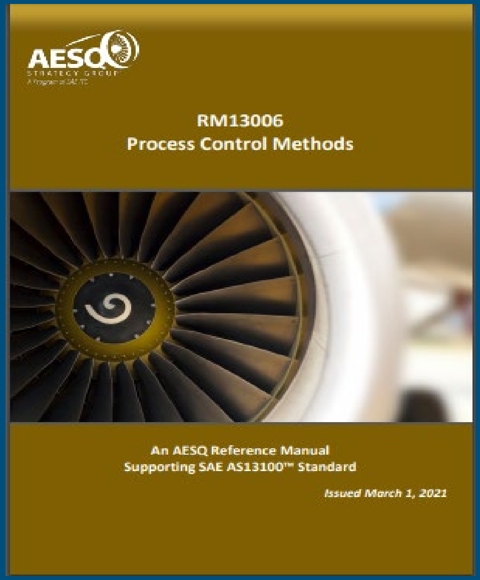
https://aesq.sae-itc.com/supplemental-material

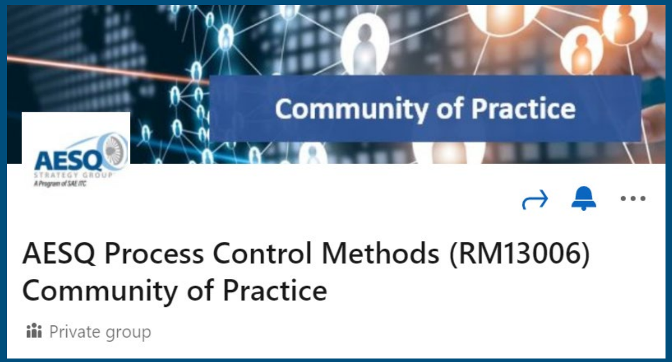
Subject Matter Interest Group – meets monthly – supports continuous improvement of RM13006 and supporting templates & tools

AESQ Process Control Methods Community of Practice (CoP) on Linked-In

Current membership is 175 – let's get some more!!

https://www.linkedin.com/groups/12647920/





WHAT IS PROCESS CONTROL?

The overall strategy employed **to reduce and mitigate product & process risks** resulting in the full achievement of Customer requirements.

Process Control includes the use of statistical and non-statistical methods that work to prevent and detect errors such that defects/defective parts are not created in the first place.

Statistical techniques

- Variable Control Charts: $\bar{X}$ & R, $\bar{X}$ & S, IX-MR, 3 way or Between/Within
- Attribute Control Charts: Counting defects with C or U, Counting defectives with NP or P

<u>Non-statistical techniques</u>

- Error/mistake-proofing
- Run Charts with Non-Statistical Limits
- **Pre-Control Charts**
- Life/Usage Control
- Visual Process Check and Checklist
- First Piece Check
- Test Piece Evaluation

Statistical and Non-Statistical Methods together drive reduction and control of variation.

NON-STATISTICAL PROCESS CONTROL METHODS

When to use and advantages

- If process can be mistake proofed
- If process tends to drift
- If process data does not easily lend itself to statistical methods
- Easier for operators to understand and accomplish
  - Can be done on shop floor
  - Immediate feedback, no waiting for data analysis
  - Usually less expensive than statistical methods

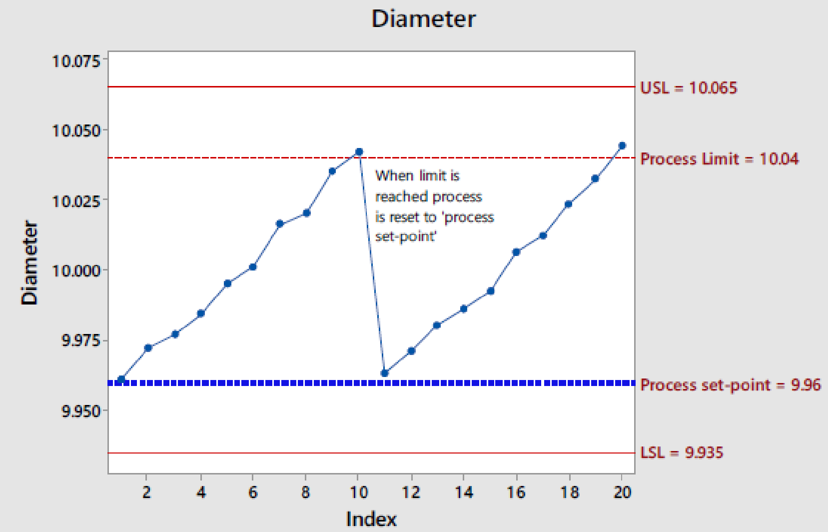
MISTAKE PROOFING LEVELS

Level	Description	Examples
1	Error prevented from ever occurring at its source – One-way assemblies – Automatic calculations – Computerized forms that prevent processing with missing data.	
2	Error detected and corrected during the process – Alarms – Lights – Control charts – Delete key “Are you sure?” prompt	
3	Error detected after process, but prior to customer – Inspections prior to the next operation – Standard work documents	

Error prevented

Error detected during

Error detected after

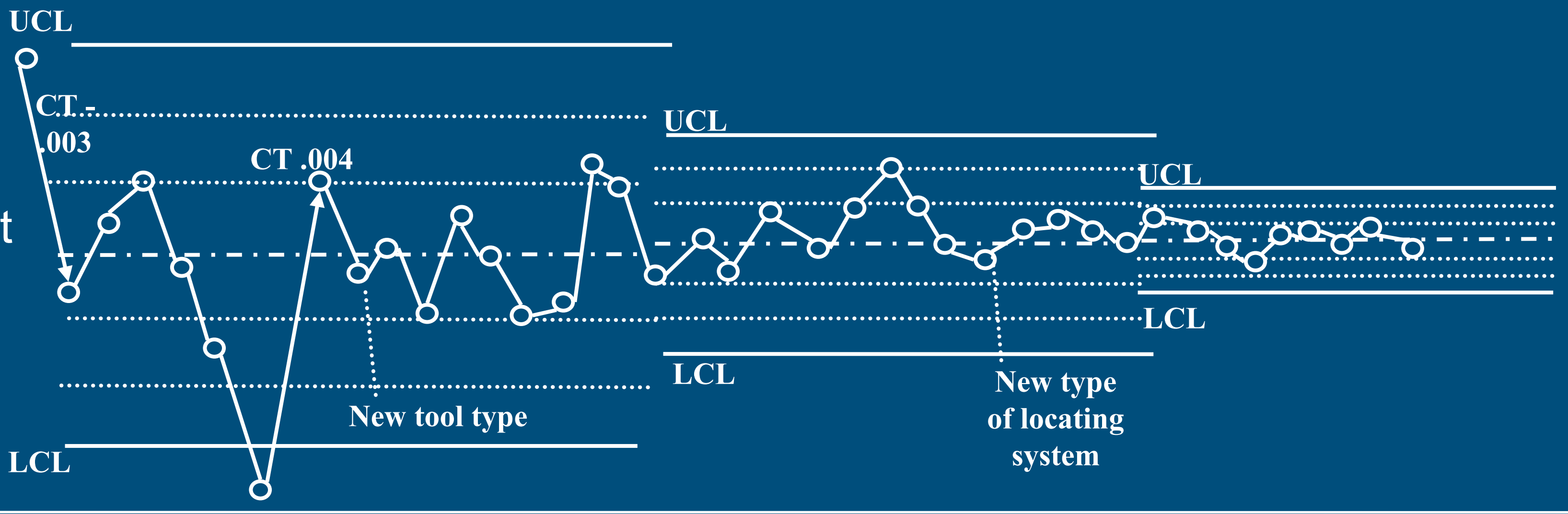


NON-STATISTICAL PROCESS CONTROL METHODS

When **not** to use

- Process capability metrics are needed to meet customer or organizational requirements.
- If data is needed for process development / improvement.
- If you need to maximize the potential of the process.

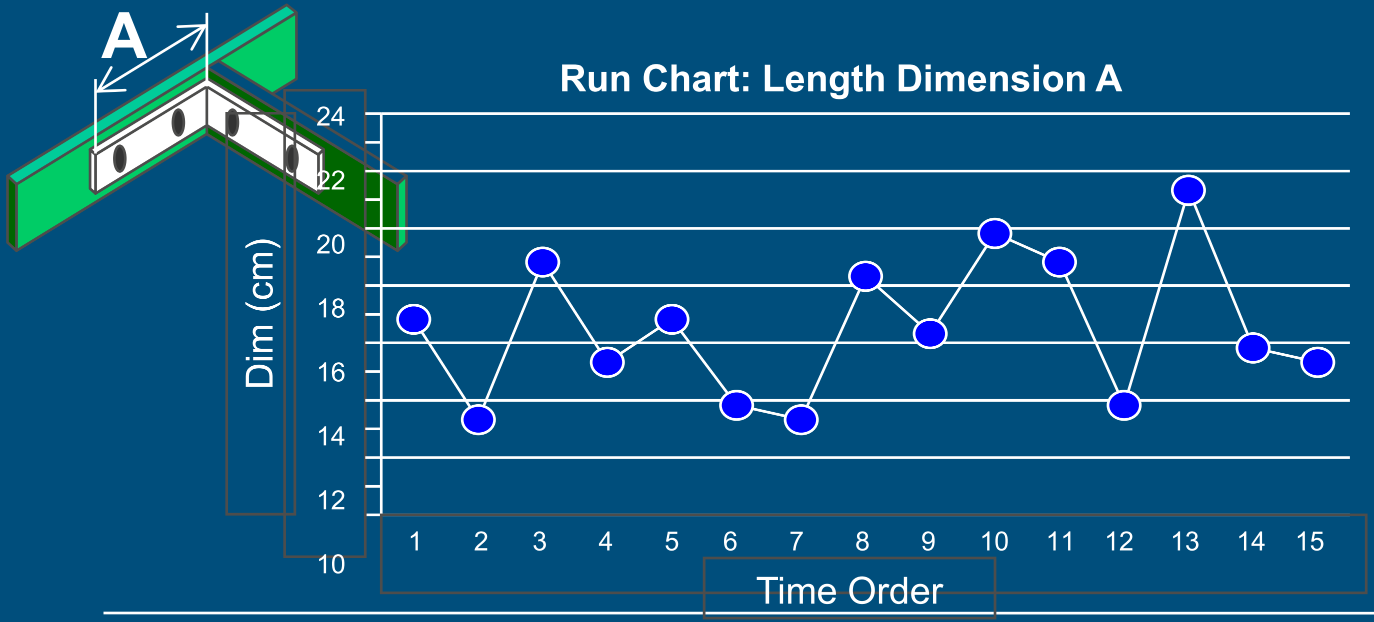
Statistical Control Chart showing process improvements



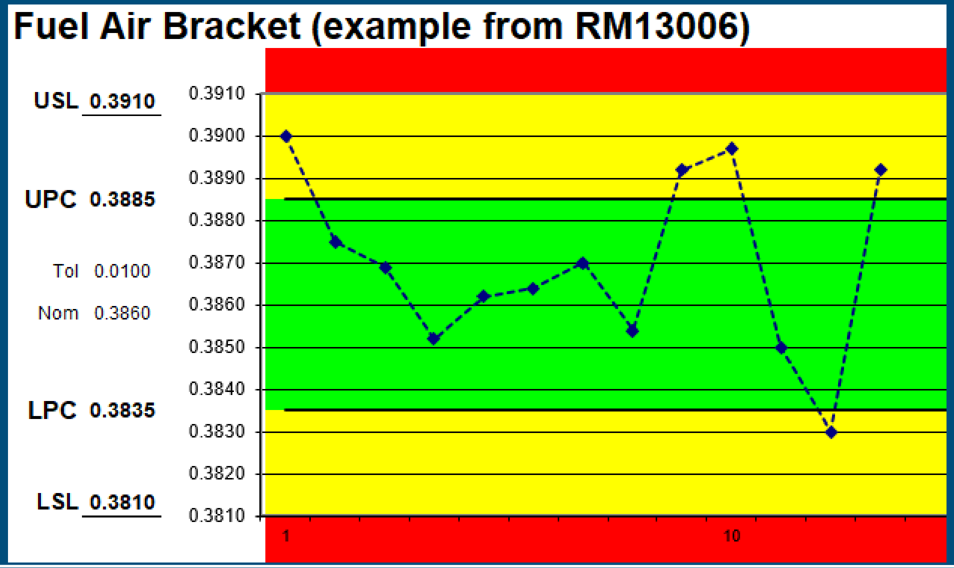
NON-STATISTICAL METHODS

Non-Statistical Charts

Run Charts	Pre-Control Charts	Control Charts
• Collect data • Monitor process	• Collect data • Monitor process • **Steer process** • **Prevent defects**	• Collect data • Monitor process • **Verify stability** • **Verify capability** • **Maximize the potential of the process**



Example Pre-Control Chart



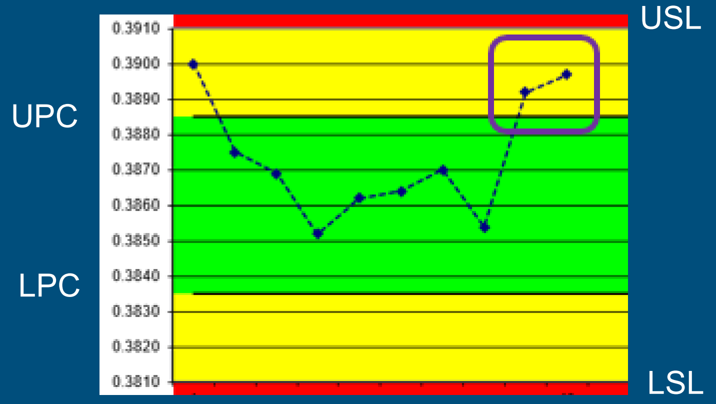
PRE-CONTROL - BACKGROUND

Why is it called Pre-Control?
You get your control limits before you even begin production

Developed in 1953 by Frank Satterthwaite, as part of a team at Rath & Strong consultants, as an easier alternative to Shewhart control charts. Dorian Shainin was part of the team and was key to the method's popularization.

Classify parts as green, yellow or red.
Based on a small sample, you determine when to stop and investigate or adjust the process.

Quick response = good process control, defect and scrap reduction.



PRE-CONTROL PER RM13006

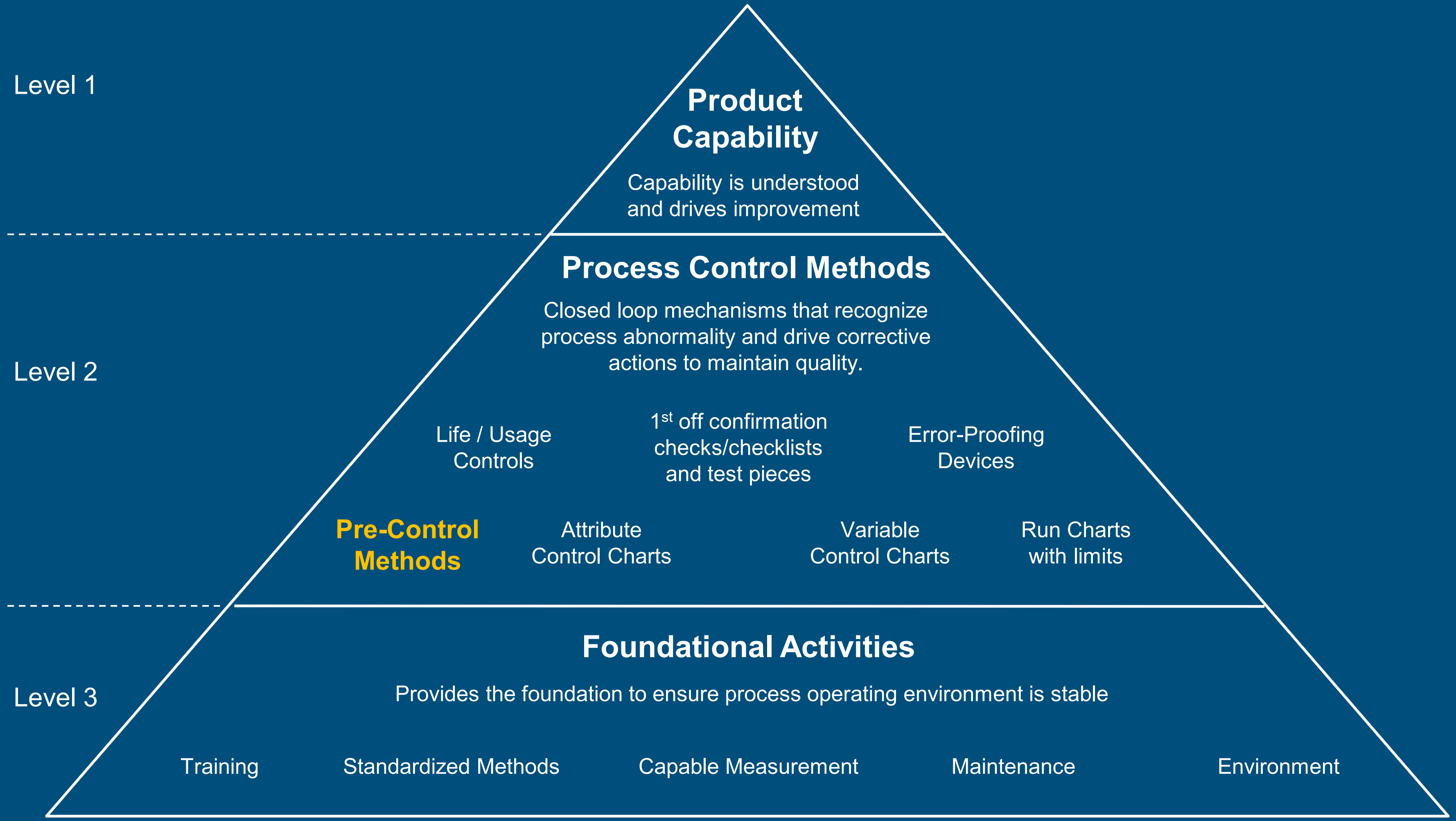


Figure 5 – Process Control Overview

PRE-CONTROL PER RM13006

4.1 Nine Recognized Process Control Methods – Table 1

5.4 Pre-Control Charts

7.1.2 Data Transformation and Transformed Limits

12.3 Resistance to SPC
f. “SPC is only useful once we have 30 data points”

Appendix C Training Syllabus
Application of Control Charts

1. Error/Mistake Proofing
2. Control Charts for Variable Data
3. Run Charts with Non-Statistical Limits
4. **Pre-Control Charts**
5. Life/Usage Control
6. Attribute Control Charts
7. Visual Process Check and Checklist
8. First Piece Check
9. Test Piece Evaluation

PRE-CONTROL PER RM13006

From Table 1 in section 4.1

Method	Application	Example
Pre-Control Charts	**To keep a capable process on target when the process has a tendency to move from the nominal value. Where processes are not sensitive to small changes,** the use of a statistical Control Chart offers little additional value. **When simple operating rules are beneficial.** **Typical reaction:** Pre-Control Charts have **"warning limits"**. The action required is either one of **further monitoring or action to investigate** the reason for the process running off target. The reaction will depend on the ruleset being used.	Correct setup of a fuel control valve grinding process is confirmed by running the process and making adjustment until process is centered. Once centered, the process is monitored and only adjusted when Pre-Control rules are broken. Monitoring of the outside diameter of an air cycle machine shaft where the operator controls adjustments using a machine offset in response to signals on the Pre-Control Chart.

PRE-CONTROL PER RM13006

5.4 Pre-Control Charts

5.4.1 **Background**

Pre-Control is a method for monitoring and controlling the process within specification limits. It may be **particularly useful when applied to process outputs or parameters that have a tendency to drift but for which the process is not overly sensitive to small changes.** For example, a measurement taken on a ground feature where the grinding wheel wears over time.

Pre-Control may also be useful where it is important **to maintain a capable process centered or 'on target', when detection of process 'special causes' are less important.**

NOTE: The use of Pre-Control dates back to the 1950s. The merits of its use are often debated, with some favoring and some opposing its use. There are definitely valid arguments for and against which should be considered.

Pre-Control uses a chart that monitors items by classifying the measurements into colored zones (Red, Yellow, or Green). Decisions are made whether to adjust or stop the process based on where in these zones the measurements lie.

The advantages of Pre-Control are its simplicity and that it drives behavior towards on-target thinking.

PRE-CONTROL PER RM13006

NOTE: It is commonplace for the bands to be set as follows

- **Green - the central 50% of the tolerance band (or 50% tolerance around a specific target).**
- **Yellow - outer quartiles (or remainder) of the tolerance band.**
- **Red - outside the tolerance.**

Figure 13 - Pre-Control Chart for Bilateral Tolerance

Where tolerance is **unilateral**, the chart will have a single green, yellow, and red zone

Figure 14 - Pre-Control Chart for Unilateral Tolerance

PRE-CONTROL PER RM13006

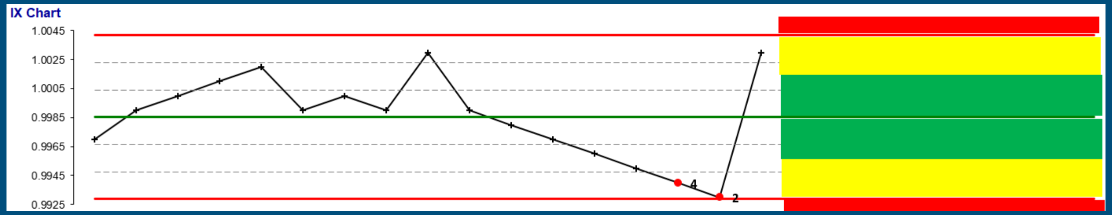
5.4.2 **Method**

Following setup, a **qualification phase** runs according to a predefined ruleset **to ensure the process is 'on target'.** Typically, qualification is passed after **five consecutive units are produced in the green zone**.

Three styles of Pre-Control exist:

1. **Classical Pre-Control:** Rules based around sampling two consecutive items periodically from a production run:
   - Single item in Yellow - continue to run (but check subsequent item).
   - Both items in Yellow - stop and investigate. Correct the process.
   - Single item in Red - stop and investigate. Correct the process.
2. **Two Stage Pre-Control:** Based on a single item being sampled periodically.
   - A single measurement in the yellow zone triggers measurement of additional items (2nd stage)
   - A single Red will trigger process to be stopped and corrected.
3. **Modified Pre-Control:**
   - A standard control chart with colored zones applied as described for Classical Precontrol (but to control limits, not tolerances).

Note: Return to 5 piece green qualification after adjustment, tool change, new operator or material.



PRE-CONTROL PER RM13006

With the exception of modified Pre-Control, the limits and rules are not statistically derived.

Opponents argue there is a **risk of process tampering (over-control), if applying Pre-Control to an incapable process; or missing special causes that would be detected by statistical control charts.** It is therefore **not advisable to use Pre-Control on processes with poor capability** or in situations where small changes in process need to be recognized.

NOTE: **If analyzing the capability of a process that uses Pre-Control methods, a statistical control chart should be constructed to ensure the process is stable prior to analysis of capability** and communication of capability indices such as Cp/Cpk.

Despite the concern of an unstable process on capability, a measure of goodness such as **extended period in green zone on a Pre-Control Chart may serve as satisfactory evidence of capability** to meet customer requirements if the customer permits this. This is more likely **for minor characteristics** than for KCs or special characteristics such as those categorized as Major or Critical.

For further reading on the subject of Pre-Control refer to Implementing Six Sigma (2nd Edition) - Breyfogle 2003. ISBN 0-471-26572-1).

PRE-CONTROL PER RM13006

5.4.3 Pre-Control Example

An aerospace manufacturer produces a Fuel Air Bracket (see Figure 15) with a key feature having an engineering tolerance of 0.386 ± 0.005 inches. The central 50% of the total tolerance (±0.0025 inches) defines the green zone.

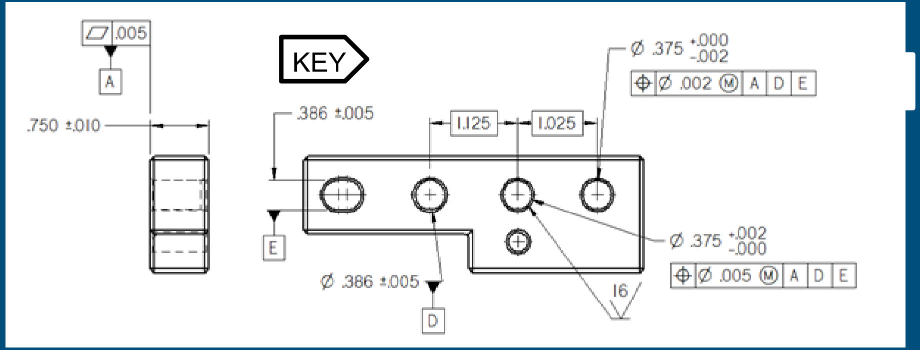


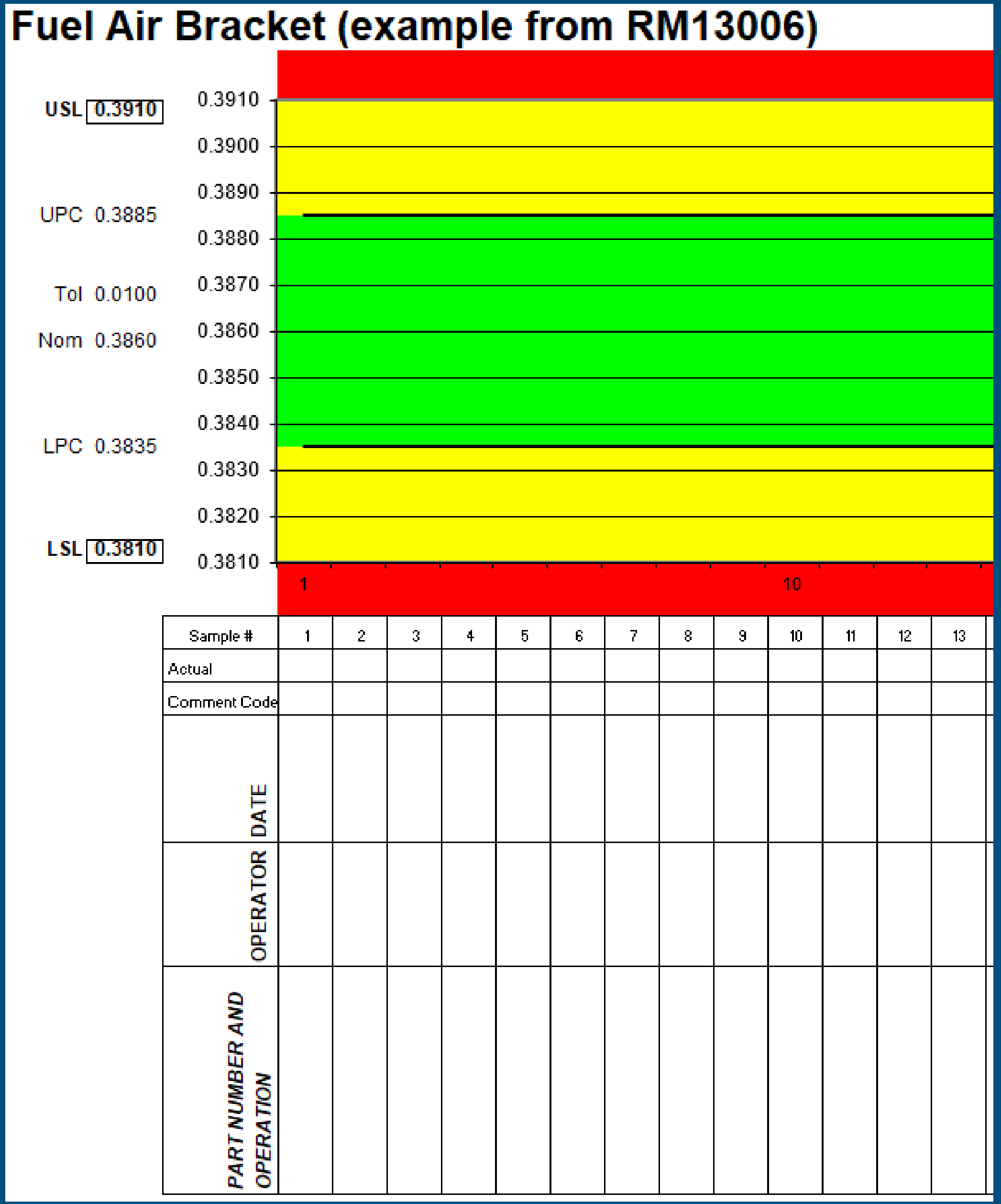
Figure 15 - Fuel Air Bracket Example

The engineer defines the zones on the Pre-Control chart. The edges of the green zone are known as Upper and Lower Pre-Control limits (UPC and LPC).

UPC limit = 0.386 + 0.0025 = 0.3885 inches.

LPC limit = 0.386 - 0.0025 = 0.3835 inches.

The control method selected is two stage Pre-Control.



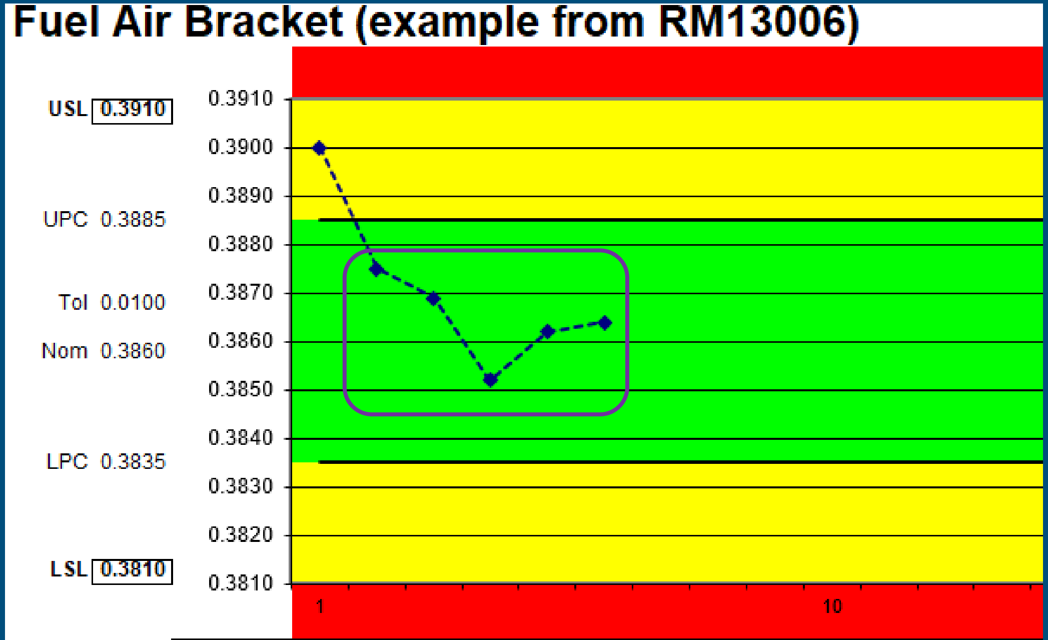
PRE-CONTROL PER RM13006

Set-Up Procedure

Following successful setup, the process operator runs five parts and records the dimensions of the features being controlled.

If all five parts fall within the green zone on the Pre-Control chart (UPC = 0.3885 inches and LPC = 0.3835 inches) the setup is judged to be targeted properly and sample measurements are taken at a frequency of 20% (check every 5th part).

This measurement frequency is for the purpose of maintaining process control and **does not relate to product inspection frequency**.



Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13
Actual	0.3900	0.3875	0.3869	0.3852	0.3862	0.3864							
Comment Code	Offset												
DATE	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023							
OPERATOR	12345	12345	12345	12345	12345	12345							
PART NUMBER AND OPERATION	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100							

PRE-CONTROL PER RM13006

Executing the Pre-Control Monitoring Technique

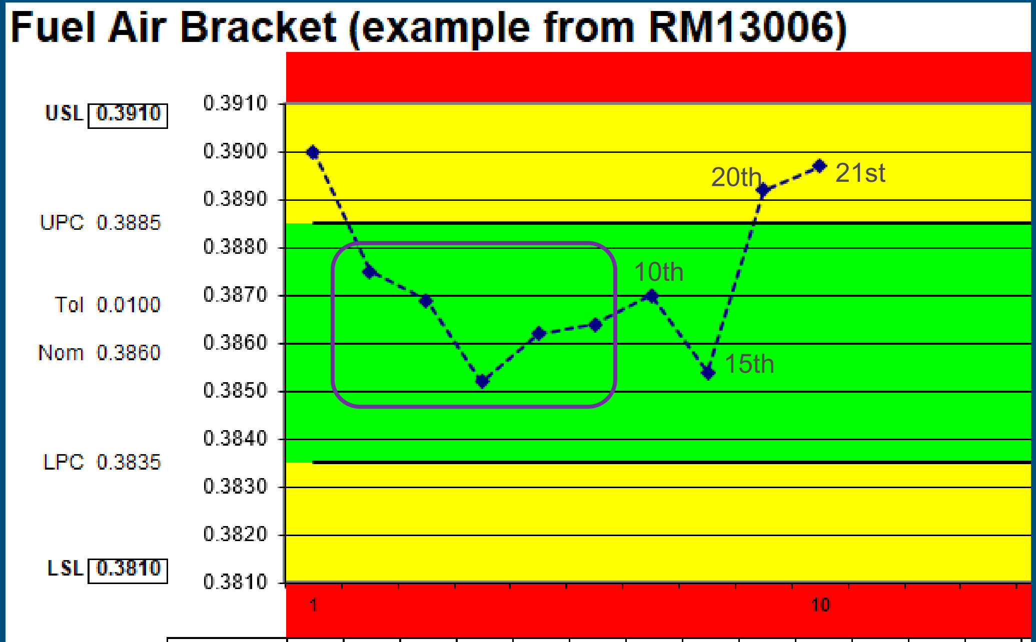
The 10th piece comes up for inspection. It has a measured value of 0.387 inches. This is within the Pre-Control (UPC and LPC) limits, and the operator continues with production.

The next piece to be inspected is the 15th. Its measurement is 0.3854 inches, well within the Pre-Control limits so the operator continues.

The 20th part measures 0.3892 inches. This value is outside the UPC limit.

The reaction plan referenced in the Control Plan determines that the operator now measures the next part produced, in this case the 21st. This part measures 0.3867 inches, again outside the UPC limit.

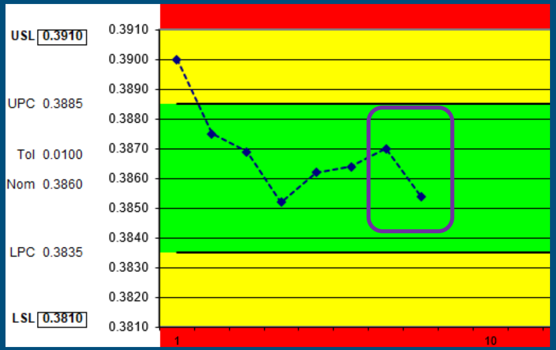
The operator stops the process and investigates according to the prescribed reaction plan.



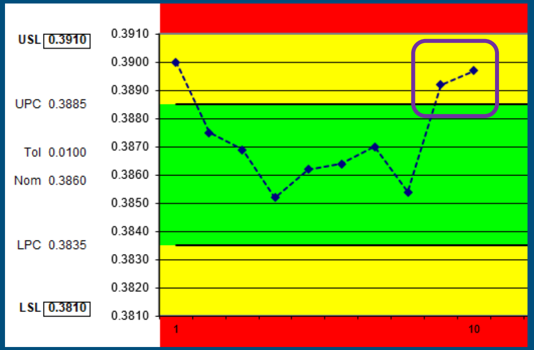
Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13
Actual	0.3900	0.3875	0.3869	0.3852	0.3862	0.3864	0.3870	0.3854	0.3892	0.3897			
Comment Code	Offset						10th	15th	20th	21st			
DATE	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023	19 Mar 2023	20 Mar 2023	20 Mar 2023	20 Mar 2023	20 Mar 2023			
OPERATOR	12345	12345	12345	12345	12345	12345	12346	12346	12346	12346			
PART NUMBER AND OPERATION	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100	123456-01 Op100			

PRE-CONTROL PER RM13006

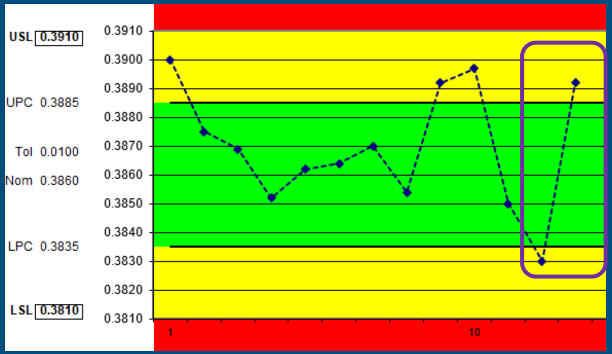
Pre-Control Rule 1: If the measured value is within the green zone (Pre-Control limits UPC and LPC) the operator may continue to check every 5th part (apply a 20% monitoring frequency).



Pre-Control Rule 2: When two consecutive measured values fall outside the same Pre-Control limit (UPC and LPC), the operator should react making an appropriate process adjustment. The reaction plan reference in the Control Plan (refer to RM13004) should describe the actions required.



Pre-Control Rule 3: When one measurement violates one Pre-Control limit and the following part violates the opposite Pre-Control limit, the variability may have increased. The operator should investigate the cause engaging support if needed (e.g., Quality/Manufacturing Engineer). The reaction plan referenced in the Control Plan (refer to RM13004) should describe the actions required.



PRE-CONTROL

Considerations & Options

- Modified Pre-Control has a large false alarm rate, so is not recommended
- The PreControl methods described by Breyfogle and others involve additional checks:
  - Take a sample of 2 consecutive measurements
  - Classical Pre-Control
    - When two in yellow: stop
  - Two-Stage PreControl
    - When two in yellow, continue to sample up to 3 more measurements
      - Continue if combined sample has 3 green
      - Stop if combined sample has 3 yellow or one red
- **Short production runs with smaller and smaller lot sizes** makes traditional SPC more challenging.
  - Short Run Charts can help, but involve coding the data, estimating target R-bar, or target s-bar, target x-double bar, etc.
  - Group Charts for multiple similar characteristics, with plotting of max and min within each group.
  - Deviation from Target Charts for multiple similar characteristics with same tolerance across multiple part numbers.

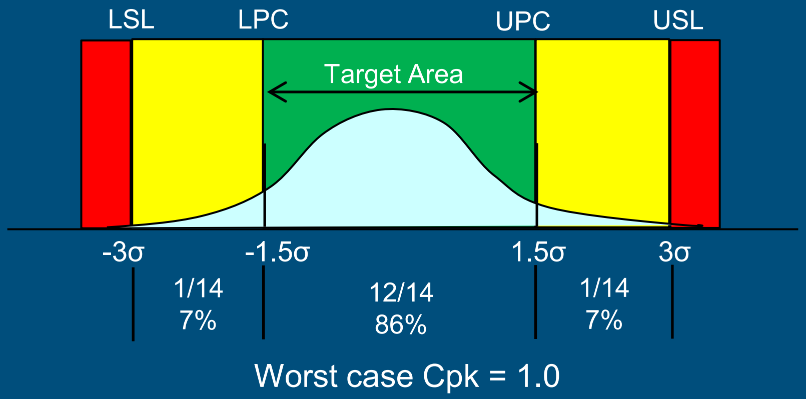
PRE-CONTROL

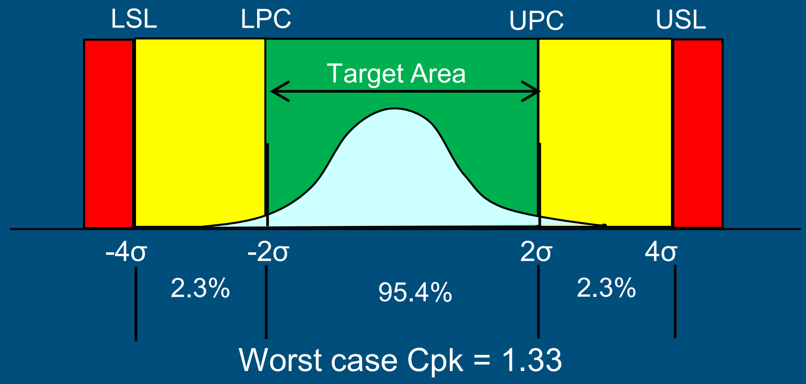
Recommendations

- Keep it simple
- Record all pieces inspected
- Use Pre-Control where ever practical
- Involve the people doing the job
- Track multiple characteristics on one chart
  - With the same tolerance
  - If automated, consider % of tolerance (middle 50% green, remainder yellow)

- Precontrol can be used for:
  - Single sided specifications
  - Attributes
  - Visual characteristics, by assigning visual standards for the Pre-Control lines

PRE-CONTROL





Theory

Alpha (α) Risk – Risk of rejecting a good process.

- If Cpk = 1
  - Probability of a yellow ~ 7%
  - Probability of two yellows in one side ~ 0.49% or 1/200
  - Total probability of two yellows ~ 2%
  - 2% risk of over correction.
  - 98% chance that a correction is needed.
- If Cpk = 1.33
  - 0.8% risk of over correction
  - 99.2% chance that a correction is needed

Beta (β) Risk – Risk of accepting a rejectable process.

- If Cp = 1 and Cpk = 1
  - 0.23% chance of not making a correction when you should, or expected average defect level.
- If Cpk = 1.33 the β risk goes to zero.

"Enormous statistical power", per World Class Quality, 2nd edition, by Bhote and Bhote.

PRE-CONTROL

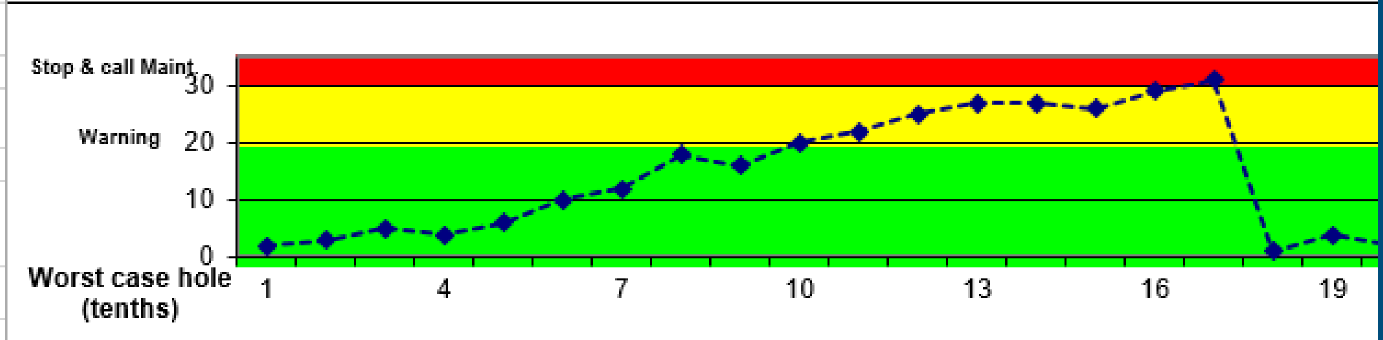
Control of Process Inputs

Example: Laser inspection of artifact

- Validate machine performing inspection
- Checked on machine
- At start of every day

Good to go
Warning: Contact Maintenance
Stop: Stop production, call Maintenance

Ex. FHEDM Artifact Validation



Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
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Date	10-Apr-10	11-Apr-10	12-Apr-10	13-Apr-10	14-Apr-10	15-Apr-10	16-Apr-10	17-Apr-10	18-Apr-10	19-Apr-10	20-Apr-10	21-Apr-10	22-Apr-10	23-Apr-10	24-Apr-10	25-Apr-10	26-Apr-10		
Badge number	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345	12345		
Comment Code	Cal									warn							cal		
COMMENT	Machine calibrated by Scott									called maint to give heads up .							calibrated by maint.		

PRE-CONTROL

Advantages

1. Ease of use.
2. No manual (or automated) calculations needed.
3. No waiting to establish control limits.
4. Quick action signals (2 measurements).
5. Good for short production runs.
6. “Stop light” control to prevent defects.
7. Hold the gains made by your improvement activity including SPC.
8. Graphical record is not necessary (but recommended).
9. With good capability, Green means go, where as Control Charts may stay stop with tight control limits.
10. Statistical control limits can cause confusion.

Disadvantages

1. Does not monitor process stability.
2. Not good if capability is < 1.
3. Not good for detecting small process changes.
4. Not very good for process improvement.
5. Potential to increase variation by over-adjustment (or tampering).
6. May need to develop charts manually or create custom software.

PRE-CONTROL

Conclusion

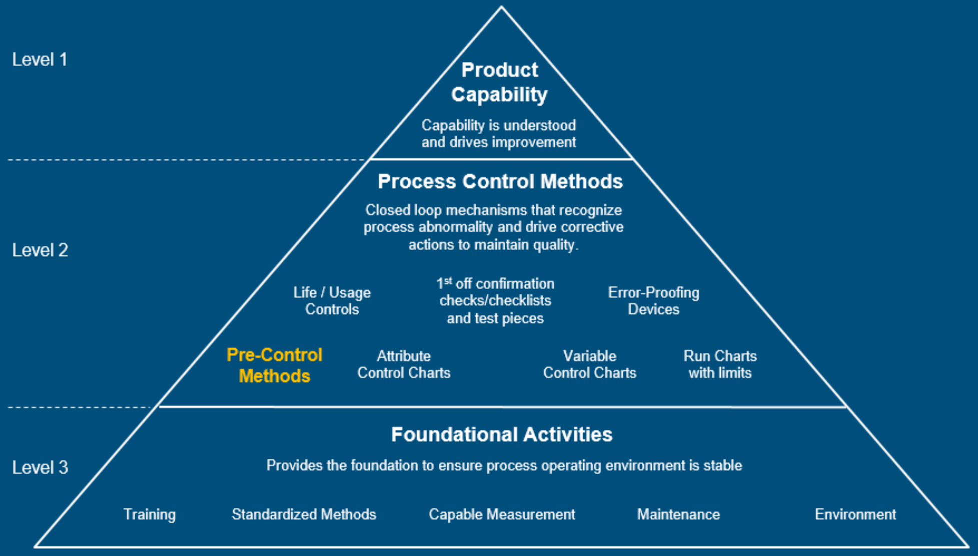

Figure 5 – Process Control Overview

Run Charts	Pre-Control Charts	Control Charts
• Collect data • Monitor process	• Collect data • Monitor process • **Steer process** • **Prevent defects**	• Collect data • Monitor process • **Verify stability** • **Verify capability** • **Maximize the potential of the process**

FUTURE WEBINARS

From the Process Control Methods SMIG Group

Look for these future topics in the "Upcoming Events" page on the AESQ website:

https://aesq.sae-itc.com/interest-groups

NO.	WEBINAR TOPICS	TARGET DATE/TIME	WEBINAR LEAD	SUPPORTING SUB-TEAM	BRIEF DESCRIPTION
1	**Process Control Methods - What is RM13006? Interaction with other AESQ Reference Manuals**	12/6/2022 (11 AM US Eastern)	Pete Teti	Nicklas Godebu/Marnie Ham	Overview of RM13006 and how it interacts with other AS13100 reference manuals.
2	**What makes a good Process Capability Study?**	1/26/2023 (11 AM U.S. Eastern)	Steve Hampton	Marnie Ham/Karen Scavotto	Cpk values are only as good as what goes into the data used to calculate Cpk, such as the adequacy of the measurement system and achieving statistical control.
3	**Process Capability for Unilateral Tolerances including True Position**	2/8/2023 (11 AM U.S. Eastern)	Andrew Stout	Grant Braun Karen Scavotto Shailesh Shinde	How do we handle process capability for one-sided or unlateral tolerances including true position where Maximum Material Condition modifiers may play a role.
4	**The use of non-statistically based process control methods**	3/8/2023 (11 AM U.S. Eastern)	Paul Gorg	Pete Teti/Earl Capozzi/Rudi Braunieder/Nicklas Godebu	Process controls need not only be statistically based. Here we explore non-statistical methods such as error-proofing devices, the PreControl method, and the use of run charts with non statistical limts.
5	**The Power of Precontrol**	4/11/2023 (11 AM U.S. Eastern)	Andrew Stout	Steve Hampton Pete Teti	PreControl is a powerful non-statistical tool that is easy to get up and running with that can be used to qualify the set-up of a lot as well as a control for the production run.
6	**The One-Hour Process Control Assessment**	5/16/2023 (11 AM U.S. Eastern)	Pete Teti		If you were visiting a supplier and only had time to carve out one hour for a process control assessment, what questions would you ask and where whom would you ask those questions to?
7	**Why is statistical control a prerequisite for process capability?**	Target 2nd Qtr (June)	Shailesh Shinde Steve Hampton		Process Capability indexes without the use of SPC Control Charts are invalid. Control Charts are the method to monitor and control a process and are a key prerequisite prior to calculating Cp & Cpk.
8	**Dealing with Non-Normal Data**	Target 3rd Qtr. (September)	Karen Scavotto	Marnie Ham/Shailesh Shinde/Andrew Stout	What happens when the data coming from a process is non-normal? What can be done to accurately assess process capability? We will show you!
9	**Conducting capability studies for one-sided geometric tolerances**	Target 4th Qtr. (October)	Karen Scavotto	Marnie Ham/Shailesh Shinde/Andrew Stout	Aerospace component manufacturers the world over deal with geometric/one-sided features such as runout, flatness, etc. What rules have to change when assessing process capability?

Q & A SESSION

USE THE “CHAT” FUNCTION TO ASK A QUESTION…

SUMMARY

All resources will be available on the AESQ website within a few days.

An email will be sent to all registrants with a link.

THANK YOU FOR PARTICIPATING

Precontrol

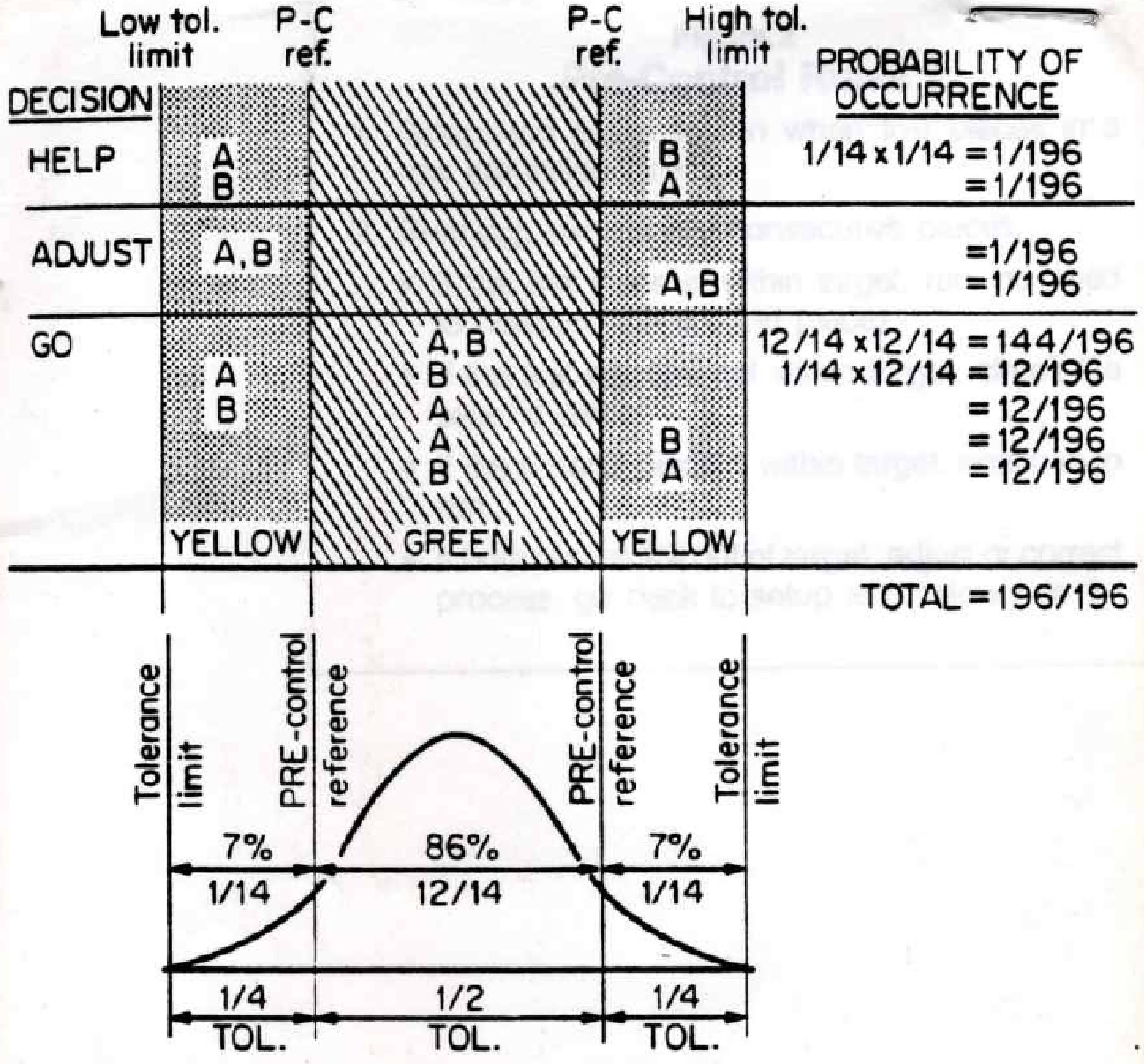

FIG. 24.16 PRE-control α risk calculation.

NON-STATISTICAL METHODS

Non-Statistical Control Charts

Advantages	Disadvantages
• No prior statistical knowledge required for application. • No "pre-run" required to set limits. • Simple and direct way of guiding a process (can be done manually). • Process control also possible with simpler measuring systems (e.g., outside mic).	• Warning limits based on assumptions or arbitrary determinations. • Range control is not part of the monitoring. • No determination of natural variation and when it's left. • Error causes often not sufficiently identified and eliminated.

Possible Applications
• Directly at the machine, as part of self-inspection. • Adjustment can be made right away or for next piece. • For processes following a Normal distribution. • Unable to make further process improvement. Hold the gains. • For highly capable processes with Ppk > 2 (narrow statistical control limits).