Control Tools

The Control Tools:

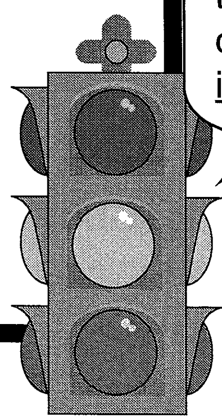
What makes SPC a good control tool?

- Processes vary because they are influenced by common-cause variation (white noise) and special-cause variation (black noise).

- Common and special-cause variation may be seen in your process:
  - common-cause variation is characterized by-steady state stable process variation.
  - special-cause variation is characterized by outside assignable causes acting on the process variation.

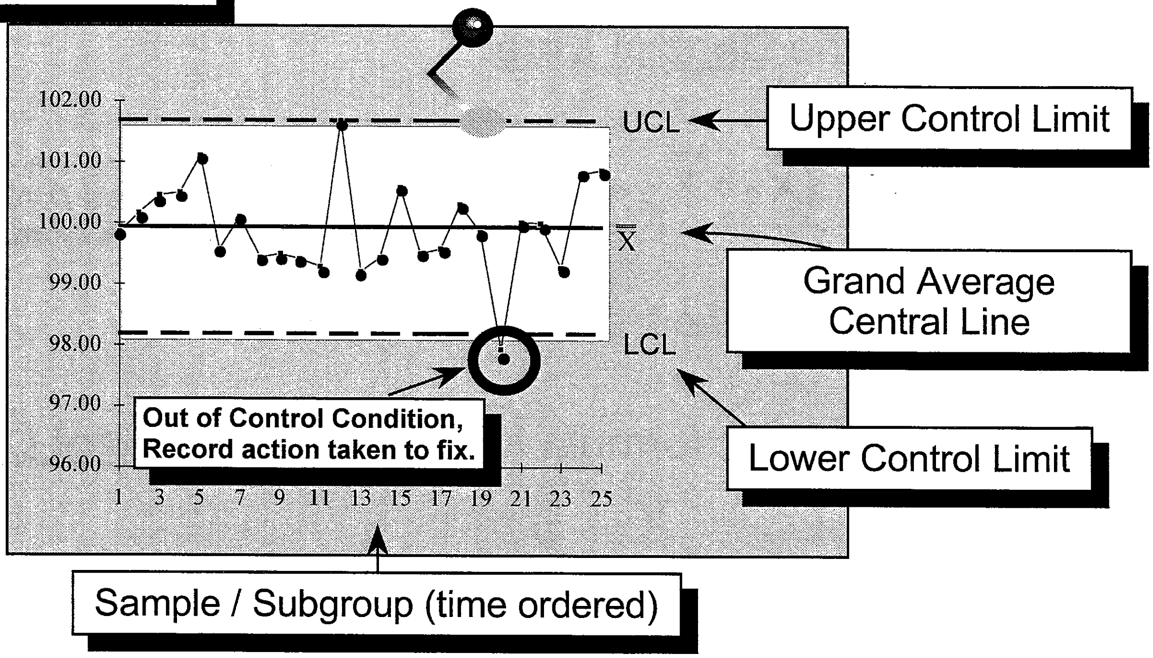
SPC will signal when the process is "out-of-control". <u>Your mission is to find out why</u>!

SPC signals when the steady-state process variation has been influenced by <u>outside</u> assignable causes.

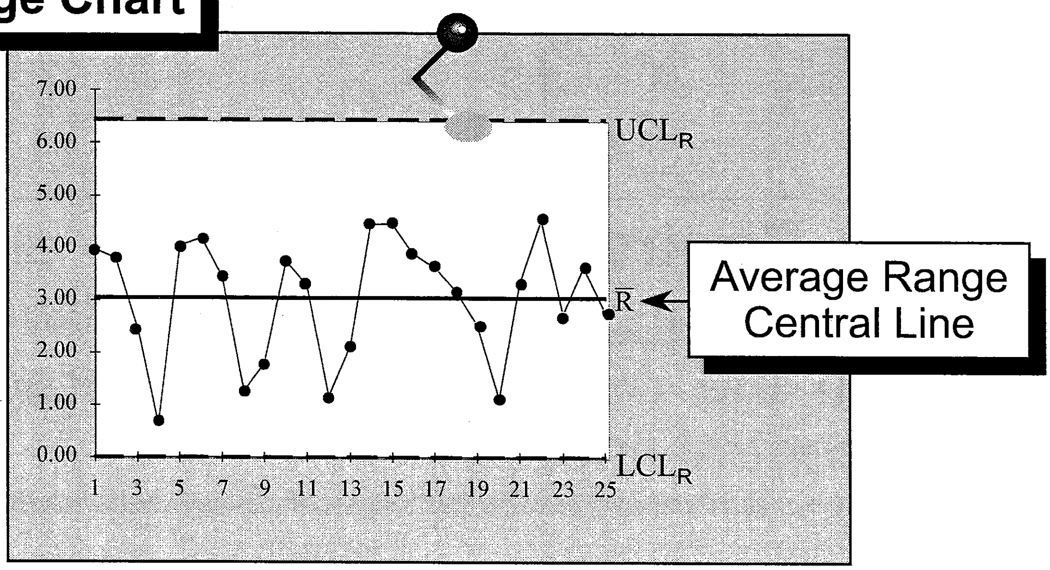


Control Chart Components

X Bar Chart



Range Chart



Why Three Sigma Limits?

Q: Why do control charts use three sigma limits?
A: Three sigma limits have withstood the test of time. If we set the limits at six sigma, 99.9999...% would be within the limits and the test would not be as sensitive to process change.

Control charts are used because they will indicate when a signal is present in a stable process.

Two mistakes commonly made when interpreting data:
– Interpreting the noise as if it is a signal
–Missing the signal when one is present
(remember the α and β errors of hypothesis testing?)

Using three-sigma limits will minimize the economic impact of both types of mistakes.

The Empirical Rules - Given a homogeneous set of data (Note: Normality is not a requirement):

1. Roughly 60% to 75% of the data will be located within a distance of <u>one</u> sigma unit on either side of the average.

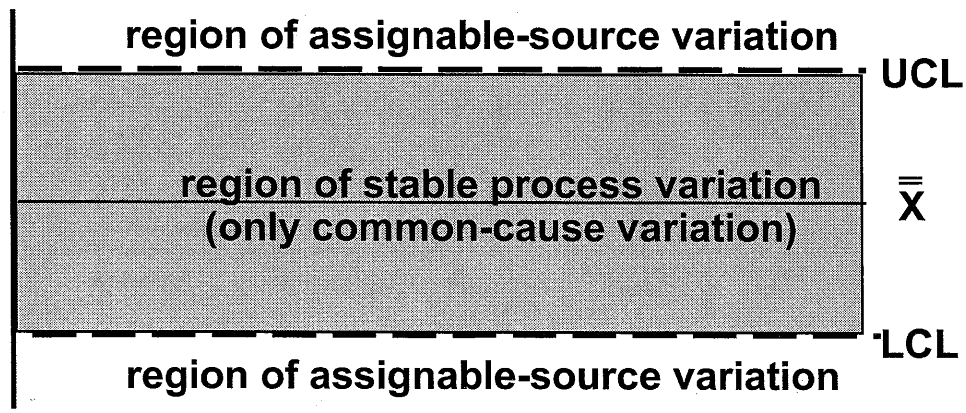
2. Usually 90% to 98% of the data will be located within a distance of <u>two</u> sigma units on either side of the average.

3. Approximately 99% to 100% of the data will be located within a distance of <u>three</u> sigma units on either side of the average.

Three-sigma limits should enclose 99% of the random-cause process variation. Data beyond the control limits should be investigated!

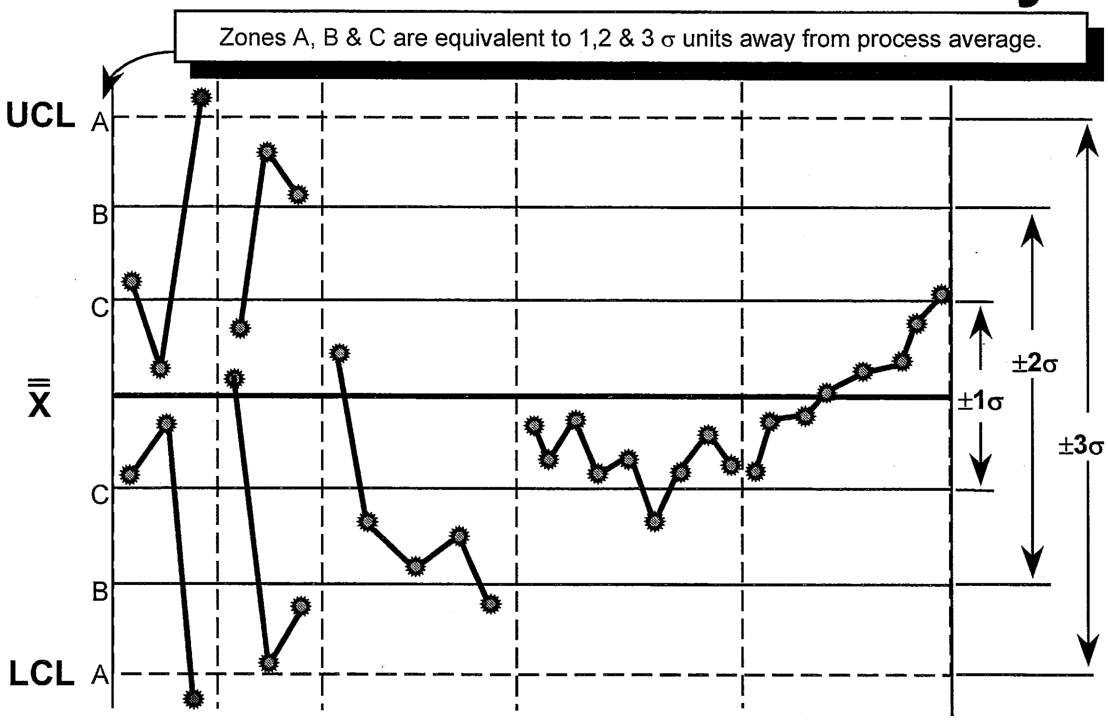
Definition of Stability

- A process output is considered stable when it consists of only common-cause variation.
- Stability also means all subgroup averages and ranges are between their respective control limits and display no evidence of assignable-source (special-cause) variation.
- If non-random patterns of data appear on the control chart, or when a point is beyond the control limits, then this is a strong signal that assignable-source (special-cause) variation is present in your process.



A stable process will rarely produce an output that lies outside of the plus and minus three sigma stable process variation region.

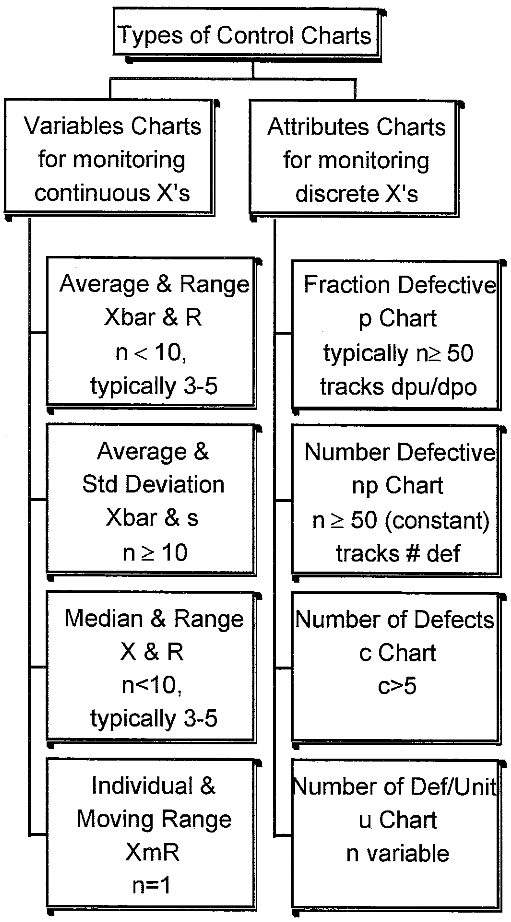
Tests for Process Instability



A lack of control ("out-of-control") is indicated when one or more of the following rules apply to your chart data:

1. A single point above or below a control limit.
2. Two out of three consecutive points are on the same side of the central line, in Zone A or beyond.
3. Four out of five consecutive points are on the same side of the central line, in Zone B or beyond.
4. At least eight consecutive points are on the same side of the central line, in Zone C.
5. A trend or repeating pattern (eight consecutive points increasing or decreasing or pattern repeated eight times in a row).

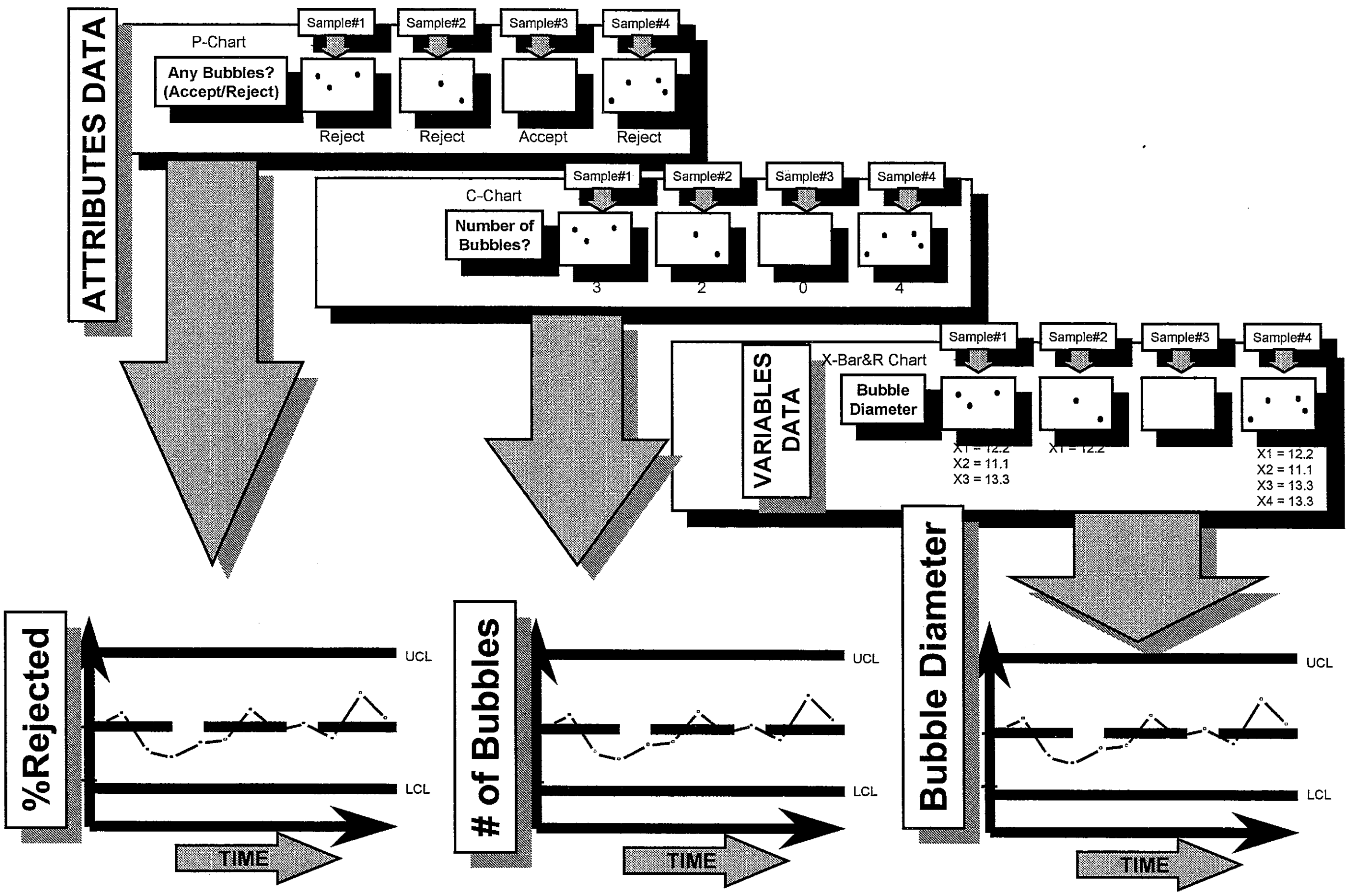
Types of Control Charts



- There are basically two types of control charts:
  - <u>Variables</u> charts - these charts are used for monitoring X variables that are continuous, such as a diameter or consumer satisfaction rating.
  - <u>Attribute</u> charts - these charts are used for monitoring discrete X variables, such as good/bad counts, or inventory levels.
- Refer to the diagram at left for a summary list of the specific control chart types

In order to select the appropriate control chart to monitor your process, first determine if the key process variables (X's) are continuous or discrete. There are specific control charts for both continuous data and discrete data.

Three Families of Control Charts



While the independent variable is different, all three types of charts are interpreted the same way.

Let's look at an example of a Variables control chart...

A consumer services organization wants to monitor "consumer satisfaction" for their company. Each week, a survey from each of the company's ten regional service centers is evaluated and the scores are tabulated. The following is an example of how an Xbar/R control chart could be used to monitor "consumer satisfaction". (In this example, higher is better.)

The vital information for creating an Xbar/R control chart:

Total subgroups = 25
Subgroup size, n = 10
Process average, $\overline{\overline{X}} = 4.096$
$\overline{R} = 0.4504$

Control Limit Formulas:

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2 \times \overline{R}$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2 \times \overline{R}$$

$$UCL_R = D_4 \times \overline{R}$$

$$LCL_R = D_3 \times \overline{R}$$

While it is acceptable to compute <u>temporary</u> control limits after 5 to 10 subgroups, **permanent** limits require at least 25 subgroups of data points that are "in-control" for both the average and range charts.

<u>Actual Control Limit Calculations for the Data</u>

$$UCL = 4.096 + 0.308 \times 0.4504 = 4.235$$

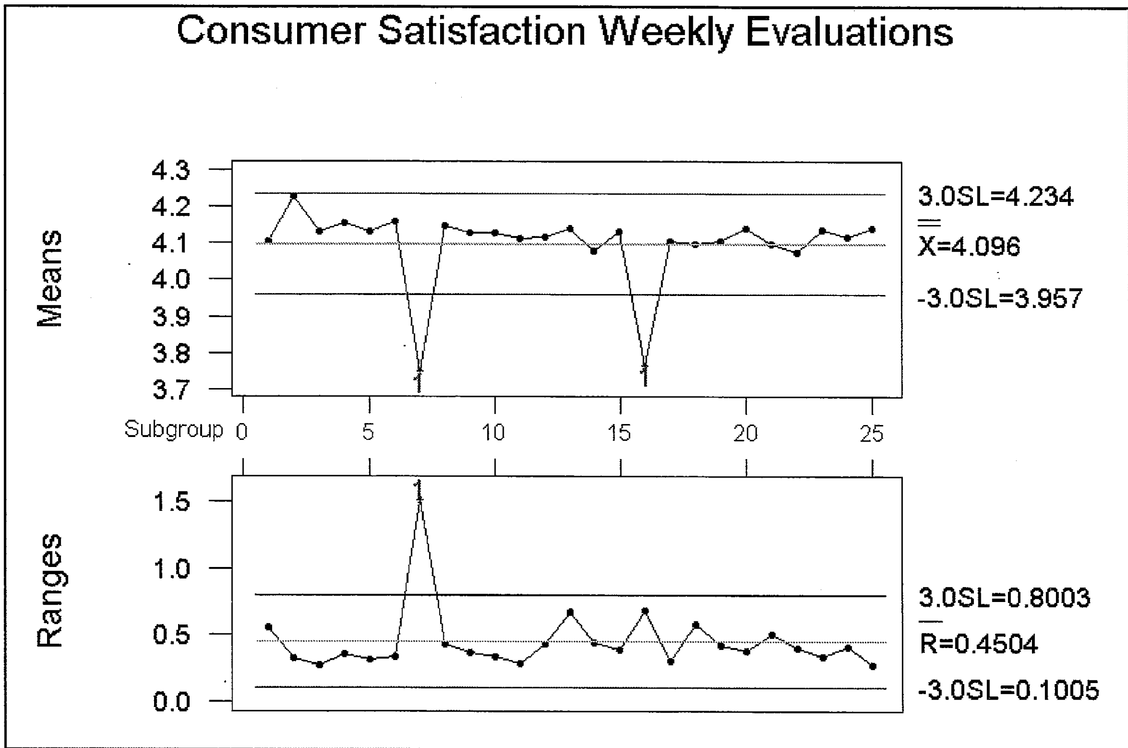
$$LCL = 4.096 - 0.308 \times 0.4504 = 3.957$$

$$UCL_R = 1.777 \times 0.4504 = 0.8003$$

$$LCL_R = 0.223 \times 0.4504 = 0.1005$$

See the SPC table of constants on page 4 ~~X~~.20

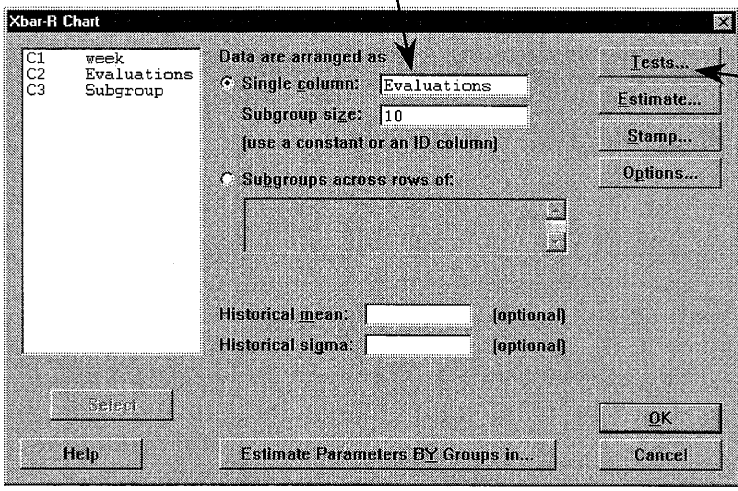
Analyzing the Control Charts



- The weekly evaluation averages 7 and 16 fell below 3.957 - the out of control condition.
- This change in "consumer satisfaction" score was driven by some assignable cause (either system-related or region-initiated).
- The appropriate action would be to investigate, identify and fix the assignable source of the variation. You should record this on the chart at the time of <u>occurrence</u>.
- The variation among the regional centers for week 7 is larger than expected. This also requires investigation and correction. The reason and action taken should be noted.

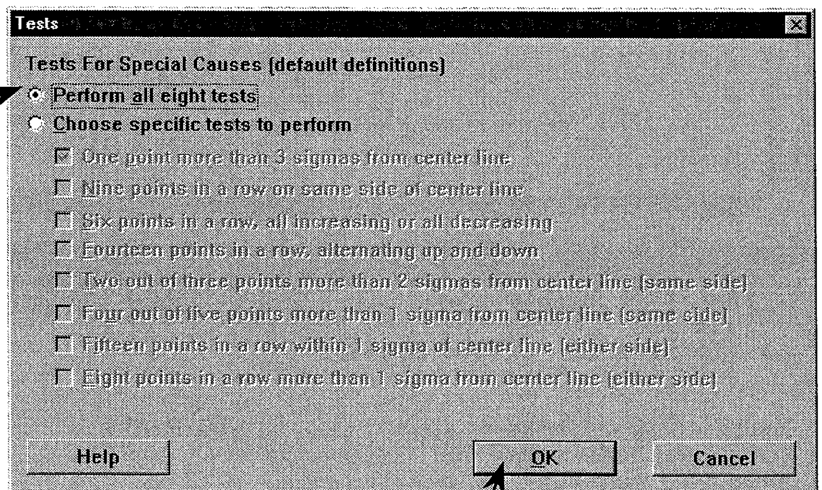
An "out-of-control" indication can come from either chart, independently.

Select the column with the response data and enter the subgroup size.



Select **'Tests'.**

Decide on test criteria for out-of-control conditions.



Select OK twice.

An Attribute Control Chart Example

A local dental group wanted to know why a lot of their patients fail to keep their appointments. A problem solving team was assembled, and decided to use a p Chart to track the percentages of "no shows". The dental clinic began logging monthly percentages of "no shows" for each month. Of the total appointments for each month, % "no shows" plus % "shows" equal 100%. Since a "no show" is a defective appointment, the average total fraction defective is called $\bar{p}$.

Year	1996					
Month	Jul	Aug	Sep	Oct	Nov	Dec
% Failed	40	36	36	42	42	40
Year	1997					
Month	Jan	Feb	Mar	Apr	May	Jun
% Failed	20	26	25	19	20	18
Month	Jul	Aug	Sep	Oct		
%Failed	16	10	12	12		

p Chart Formulas:

$$p = \frac{np}{n}$$

monthly percentage defective

$$\bar{p} = \frac{n_1 p_1 + n_2 p_2 + \ldots + n_k p_k}{n_1 + n_2 + \ldots + n_k}$$

total average percentage defective for k number of subgroups

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p} \times (1-\bar{p})}{n}} \quad \text{and} \quad LCL = \bar{p} - 3\sqrt{\frac{\bar{p} \times (1-\bar{p})}{n}}$$

$\bar{p}$ = 236/600 = 0.39333, where np = 40+36+36+42+42+40 = 236
the fraction is based on 600, the total number possible for 6 months

UCL = .39333+3((.39333*.60667)/100)$^{1/2}$ = 0.539
LCL = .39333- 3((.39333*.60667)/100)$^{1/2}$ = 0.246

A Practical Approach to Applying Statistical Process Control

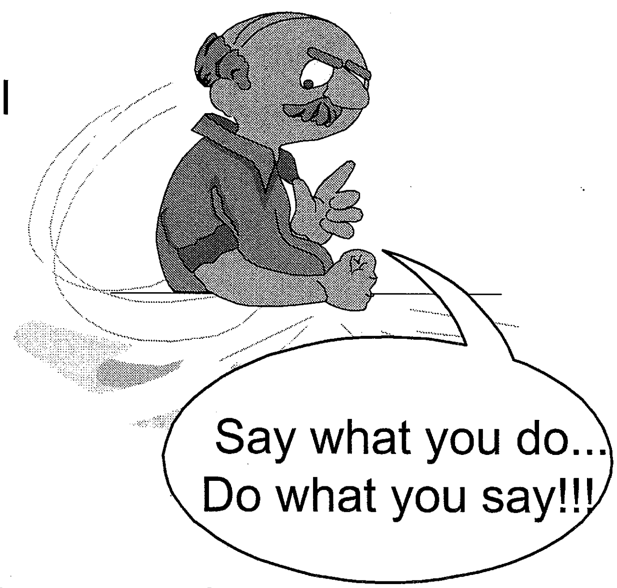
- Requires a disciplined approach to process management and data gathering.
- Works best within an automated or semi-automated environment. (It is a real-time process monitoring tool.)
- Requires an appropriate response to an "out-of-control" condition. The core of a successful SPC program is what happens when an "out of control" situation is detected.
- Should be used only where appropriate; do not paper the factory walls with control charts!
- The sensitivity of a control chart to detect non-random variation can be improved by increasing the subgroup sample size.
- Recalculate new control limits only when the process variation has truly changed (stabilized).

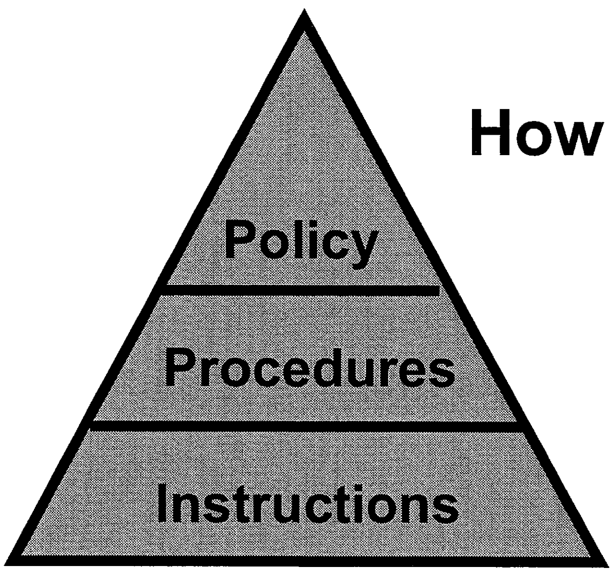
ISO - tool # 3

International Organization for Standardization

What is it?

An internationally recognized model for quality assurance used to document and implement a basic quality system so that a company has the capability to deliver the quality products or services that its customers have asked for.





How can I use it?

It is an excellent tool to document:

- Set Up Procedures
- Process Control
- Data Collection Plans
- Preventive Maintenance

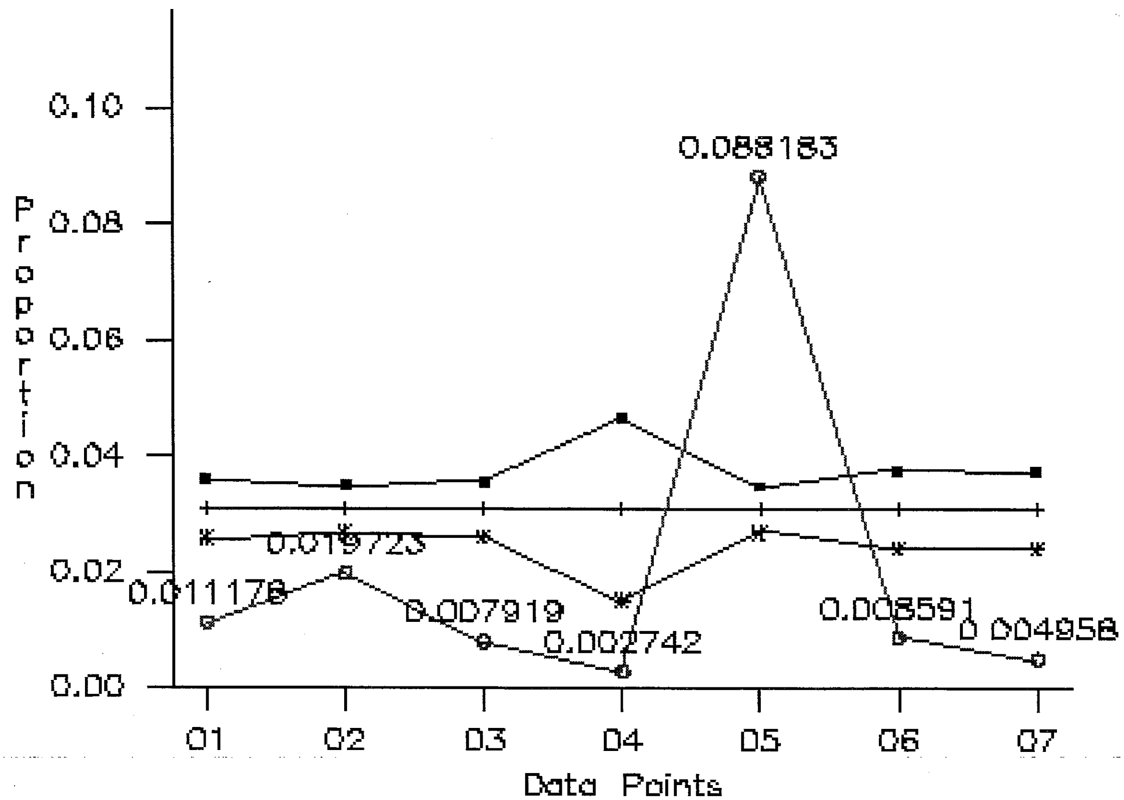
If you do a project at an ISO certified site, then you MUST update the ISO documentation as part of project closure.

SPQ - Tool #4

Supplier **P**rocess **Q**uality

<u>What is it</u>? A system for tracking the quality of parts at a supplier's plant. It is essential in the Control phase of a 6 Sigma project on supplied parts.

Chart For The Period – 10/06/1997 To 01/04/1998



SPQ - Tool # 4
Supplier Process Quality

SPQ can be used to ***ensure a process stays in control.***

It saves GE time since:
- Suppliers enter the data
- Alarms check for out of control
- Control charts are available to help resolve problems quickly.

Where can you get more information?

See the instructions in the Appendix.

Some contacts are:
MBB -- Bill Wunderlin
PMQE -- Chad Anderson
IT -- Ravishankar Jayaram

Training - Tool # 6

Project: Contract Channel Order Placement

Objective: Improve efficiency on incoming calls at the Forum by reducing call time with unprepared customers.

Training: Trained call takers on the "customer prepared" field. All of the current call takers were trained by the black belt and program manager for team development. Also, the training on the "customer prepared" field was incorporated into the training for all new call takers on the order placement system.

Internal Audits - Tool # 8

Project Title: Factory Service Scheduling

Project Description:
Reference project in Tab 2.

Internal Audit Process:

Breakdown Call Components

Description: In order to break apart the pieces that make up a schedule call, a video tape process is used to audit each segment of the call. The viewer can time call segments, verify the correct process and audit computer transaction usage. This process can be used to determine effects of minor running process changes.

Frequency: Quarterly, ASI factory service developers will analyze a sample of calls from each center.

Report out plan: Results of this analysis will be shared with the call-taking council, where appropriate business decisions can be made, if necessary.

Meetings/Reviews - Tool # 9

Project Title: Factory Service Scheduling

Project Description:

Reference project in Tab 3.

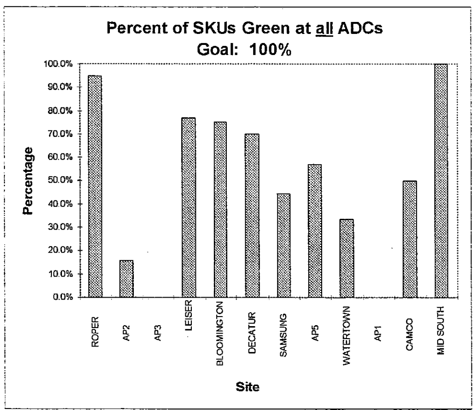
Frequency of Measurement / Measurement System:
A minimum of 300 calls per week will be monitored using any one of these processes. Scores are a percentage of points earned Vs. points available in each particular call. Scores are recorded for each rep and maintained by the site's employee development manager. Individual low scoring reps (i.e. reps below the 88% minimum score) are coached by the service rep's developer. Trend data is recorded and reported to the ASI VP-Factory Services, ***for discussion monthly at the Factory Service Call-Taking Council.***

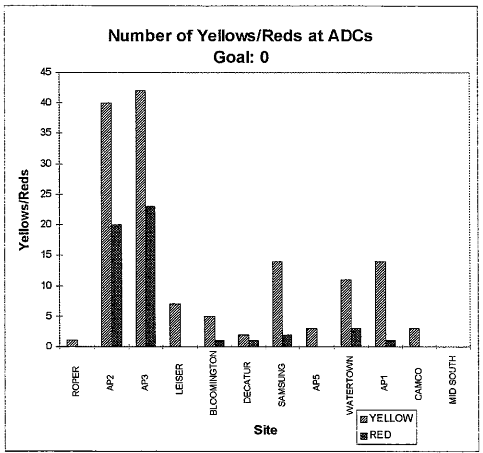
Pitfalls of Meetings...

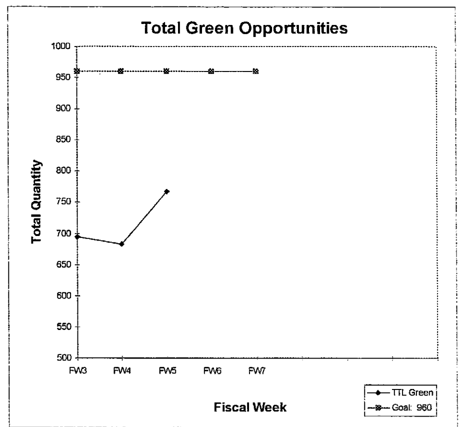
1) Can't guarantee that they won't stop

Dashboard - Tool # 10

100 x 120 Hot Sheet - page 1







	NO. of SKUs	# of Opportunities	GREEN	YELLOW	RED	Actions/Comments
ROPER	19	152	151	1	0	Good shape
AP2	19	152	92	40	20	AP2 prioritizing 120 models in schedule
AP3	17	136	71	42	23	Increase production and move to C2 line
LEISER	13	104	97	7	0	All are in transit due arrive between 2/2 and 2/11
BLOOMINGTON	12	96	90	5	1	Production today--- 1-2 weeks to fix
DECATUR	10	80	77	2	1	Red fixed 2/3, Yellows in transit fixed by 2/10
SAMSUNG	9	72	56	14	2	In transit due between 2/4 and 2/15
AP5	7	56	53	3	0	In transit, fixed by 2/10
WATERTOWN	6	48	34	11	3	Watertown changing schedules-- two weeks to fix
AP1	5	40	25	14	1	Changing schedule to early this week-- two weeks to adc
CAMCO	2	16	13	3	0	Redeploying-- fix in 1 week
MID SOUTH	1	8	8	0	0	In transit
TOTAL	120	960	767	142	51	
960 Opportunities			80%	15%	5%	

Class Exercise: Catapult Control Plan

You have been given a catapult (missile-launcher). In phase 2, your team found the critical X's and optimized them to give the best result for missile distance.

Now, your team's task is to create a control plan for the catapult, to ensure that the process improvements continue over time...

1) Critical X's
- List the critical X's for your process
- Describe the effect of the X's on the response,Y. (The "effect" should include the direction and magnitude of the effect. For example, a 1.0 pound change in X increases Y by 3.8%.)
- Develop target values and specifications for all the critical X's.

2) Documentation
- Job description and ownership
- Training plan for all involved
- Measurement calibration and maintenance
- Preventive maintenance plan
- Other appropriate documentation (ISO)

Class Exercise: Catapult Control Plan

6) Reaction plan for out-of-control situations
   - Communication plan -- who must be notified?
   - Who is responsible for getting the process back in control?
   - Define specific actions to take if the process goes out of control.
   - Record actions taken for any out of control points on the control chart.

7) Audit plan
   - Confirm $ savings.
   - Plan to periodically review the process and ensure that all procedures are being followed.

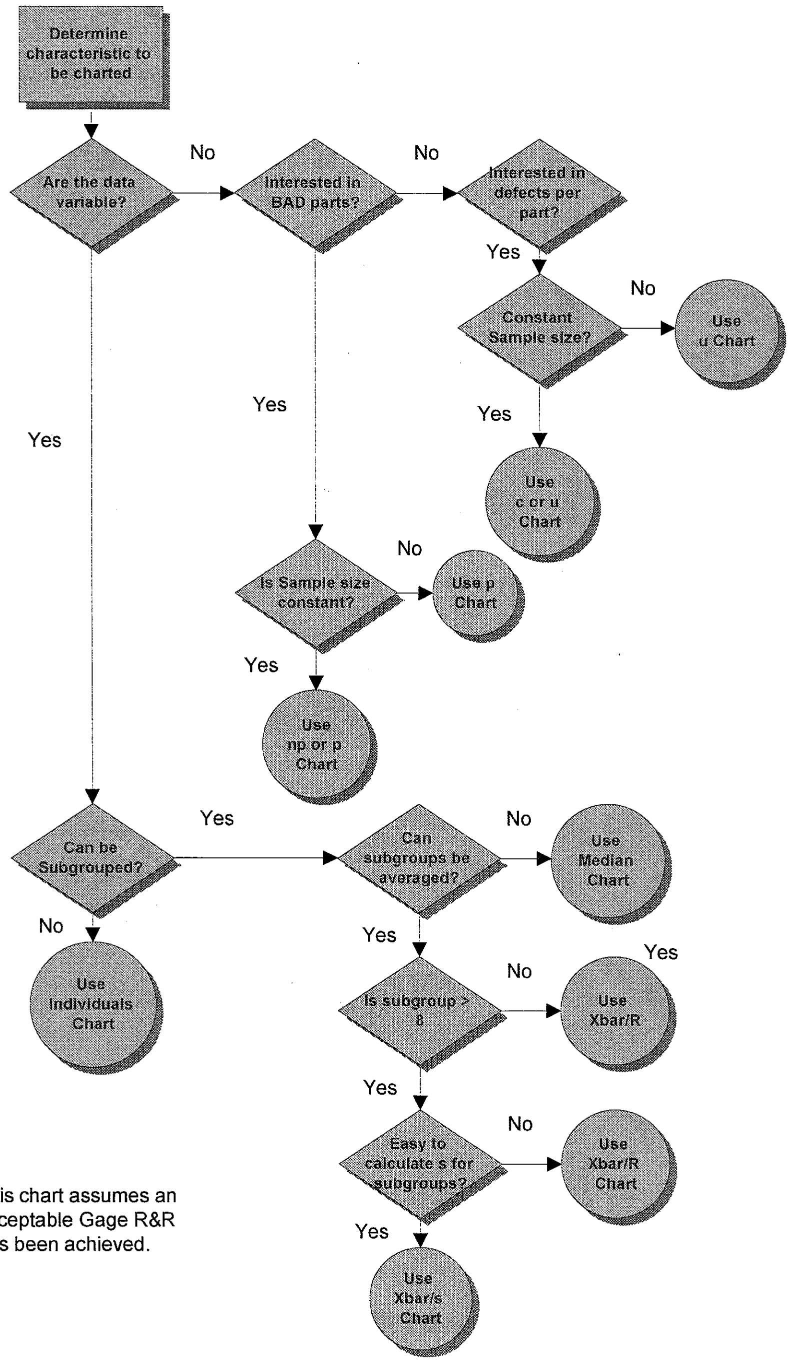
After you finish the control plan, find your next project and celebrate with your team!

Key Concepts: Control Tools

- Basic tactics for using control charts:
  - Plot data immediately.
  - Identify and react to "out-of-control" conditions.
  - Search for root cause for "out-of-control".
  - Do not make adjustments if the process is not out-of-control.
- There are many other tools besides SPC that can be used in the control plan:
  - SETCIM
  - ISO
  - SPQ
  - System changes
  - Training
  - Job descriptions
  - Internal Audits
  - Meetings and reviews
  - Dashboards

Appendix

Control Chart Selection Procedure



This chart assumes an acceptable Gage R&R has been achieved.

Attribute Control Chart Formulas

p Charts (Used to chart fraction defective)

$$p = \frac{np}{n} \text{ and } \bar{p} = \frac{np}{N}$$

Central Line Formula

$$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

np = number of defectives
n= subgroup size
N= total number defectives for all subgroups
p Charts can incorporate unequal subgroup sizes.

np Charts (Used to chart the number defective)

$$np = \# \text{defective for each subgroup}$$

$$n\bar{p} = \frac{np}{k}, \text{ for all k subgroups}$$

Central Line Formula

$$UCL_{np} = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$$

$$UCL_{np} = n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$$

Equal subgroup sizes are a requirement

Camco Quality Systems Elements

6. Purchasing: Our Purchasing process evaluates suppliers, maintains an approved suppliers list, clearly defines / identifies parts and material; and reviews purchasing documents prior to release ; Sites verify material is correct and what they ordered via dwg number/quantity.

7. Customer Supplied Product; Camco as a general practice does not use Customer Supplied Product, but rather creates our own drawing, purchases and assembles the Customer Supplied Product as we do any other part or component.

8. Product Identification and Traceability: Our procedures define how we identify & trace product by model number / serial number, and maintain identification of material in the shop.

9. Process Control: Our documented procedures explain how we control processes where the absence of contol would adversely effect quality. We generally limit these controls to CTQ stations, and use different methods such as work station instructions, operator qualification, process monitoring, standards, and Preventive Maintenance.

10. Inspection and Test: Our Camco site quality procedures explain how we accomplish Receiving Inspection and Test (via part number & quantity). Require Inprocess inspection and Testing, Final Inspection & Testing; and maintain insp.and test records.

Camco Quality Systems Elements

16. Control of Quality Records: Our procedures define which, how, when, where, and for how long we maintain quality records which show our conformance to our quality system.

17. Internal Quality Audits: Our Internal audits are scheduled on a basis of importance of the activity to Camco and conducted by persons trained and independent from the area audited. Results are recorded and Management of the area is required to take timely corrective action.

18. Training: Camco defines the training needs, provides for training and keeps records of all salaried and hourly personnel performing activities affecting quality. i.e., CTQ jobs.

19. Servicing: Servicing of product is defined as product outside the warranty period and is the responsibility of GECS. In warranty issues are dealt with as nonconforming product.

20. Statistical Techniques: Our Camco procedures identify the need for statistical tools and then document and maintain procedures to implement and control their application. Our Six Sigma toolkit is a good example of many of the statistical tools we use.