statgraphics® centurion XVII

Six Sigma Toolbox

The premier tool for advanced Six Sigma and Lean Six Sigma Implementation

Full Feature Brochure

Six Sigma and Lean Six Sigma

Six Sigma is a structured approach to business management that concentrates on improving quality by reducing process variability and eliminating major failure mechanisms. Since it relies heavily on the collection and analysis of data, statistical programs such as Statgraphics are a vital component of all serious Six Sigma implementations. Lean Six Sigma adds important concepts from lean manufacturing, which concentrates on the elimination of unnecessary resource utilization.

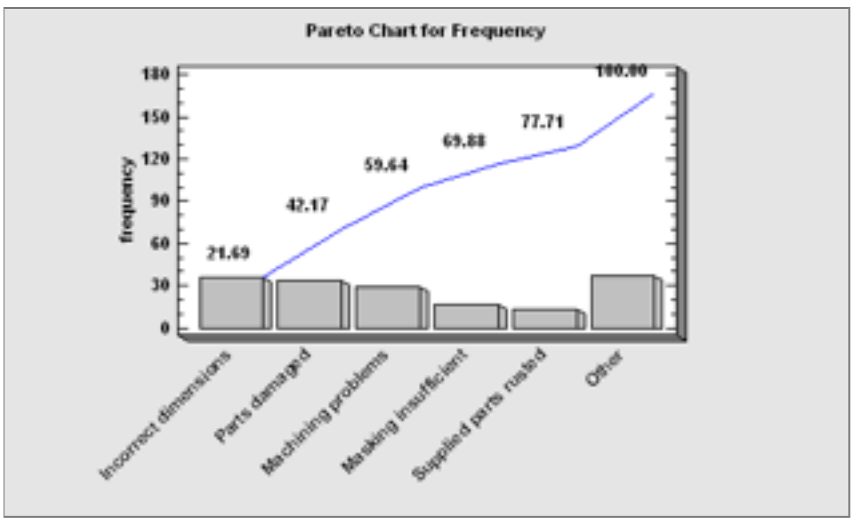
The Statgraphics Centurion Six Sigma Toolbox provides a large selection of tools for use in Lean and Six Sigma programs. The areas covered include:

1. Quality Management

When beginning a Six Sigma project, it is important to understand the problem to be addressed and the factors that most effect quality and cost. Statgraphics Centurion XVII contains several procedures that are helpful in this area.

Pareto Chart

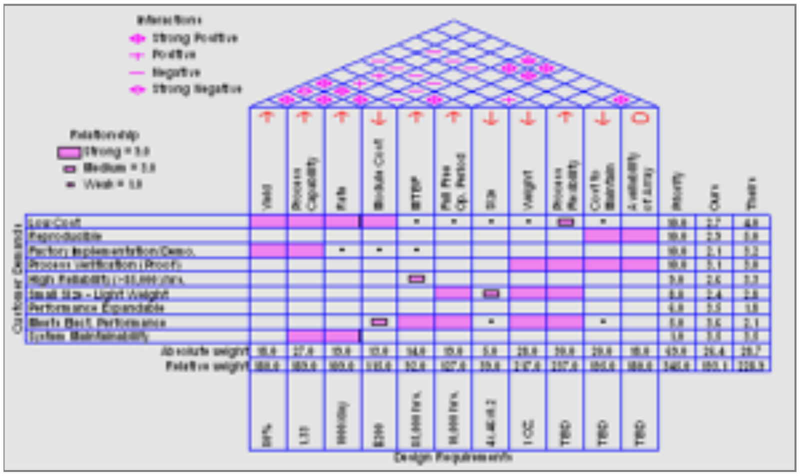
Pareto charts are often used to determine the "vital few" causes that are responsible for the majority of defects or complaints regarding a product or service.



More: Pareto Analysis.pdf

Quality Function Deployment Matrix

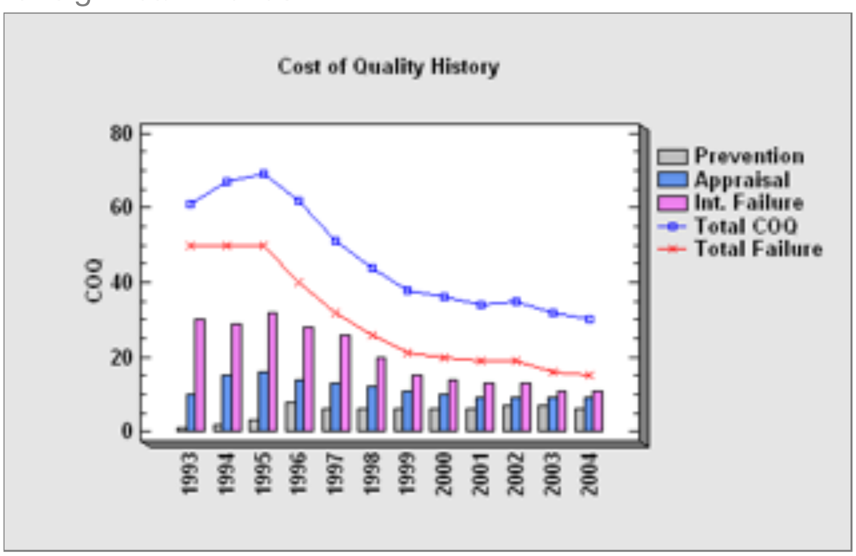
QFD is a customer-driven planning process by which products and services are matched to the needs of customers. STATGRAPHICS illustrates the relationship between customer needs and design requirements by constructing a "House of Quality”.



More: QFD Matrix.pdf

Cost of Quality Trend Analysis

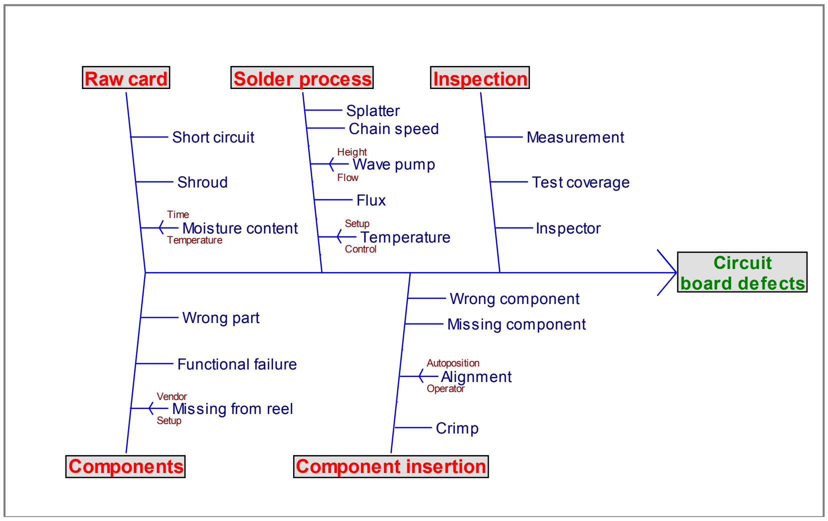
A COQ (Cost-of-Quality) trend analysis illustrates the cost of poor quality by constructing a chart displaying prevention, appraisal, and failure costs over time. Runs tests are also performed to search for significant trends.



More: Cost-of-Quality Trend Analysis.pdf

Cause-and-Effect Diagram

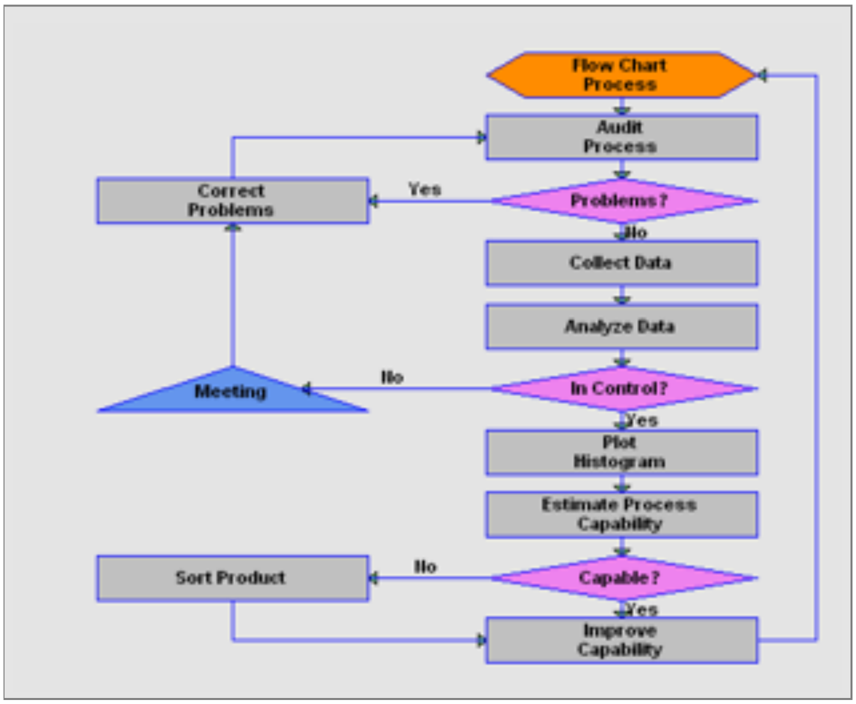
Cause-and-effect or *fishbone* diagrams illustrate the causes of a problem or effect by creating a diagram resembling the skeleton of a fish.



More: Cause-and-Effect Diagram.pdf

Process Map

Process maps are commonly used to create flow charts and other step-by-step diagrams. An example of a simple map is shown below.



More: Process Mapping.pdf

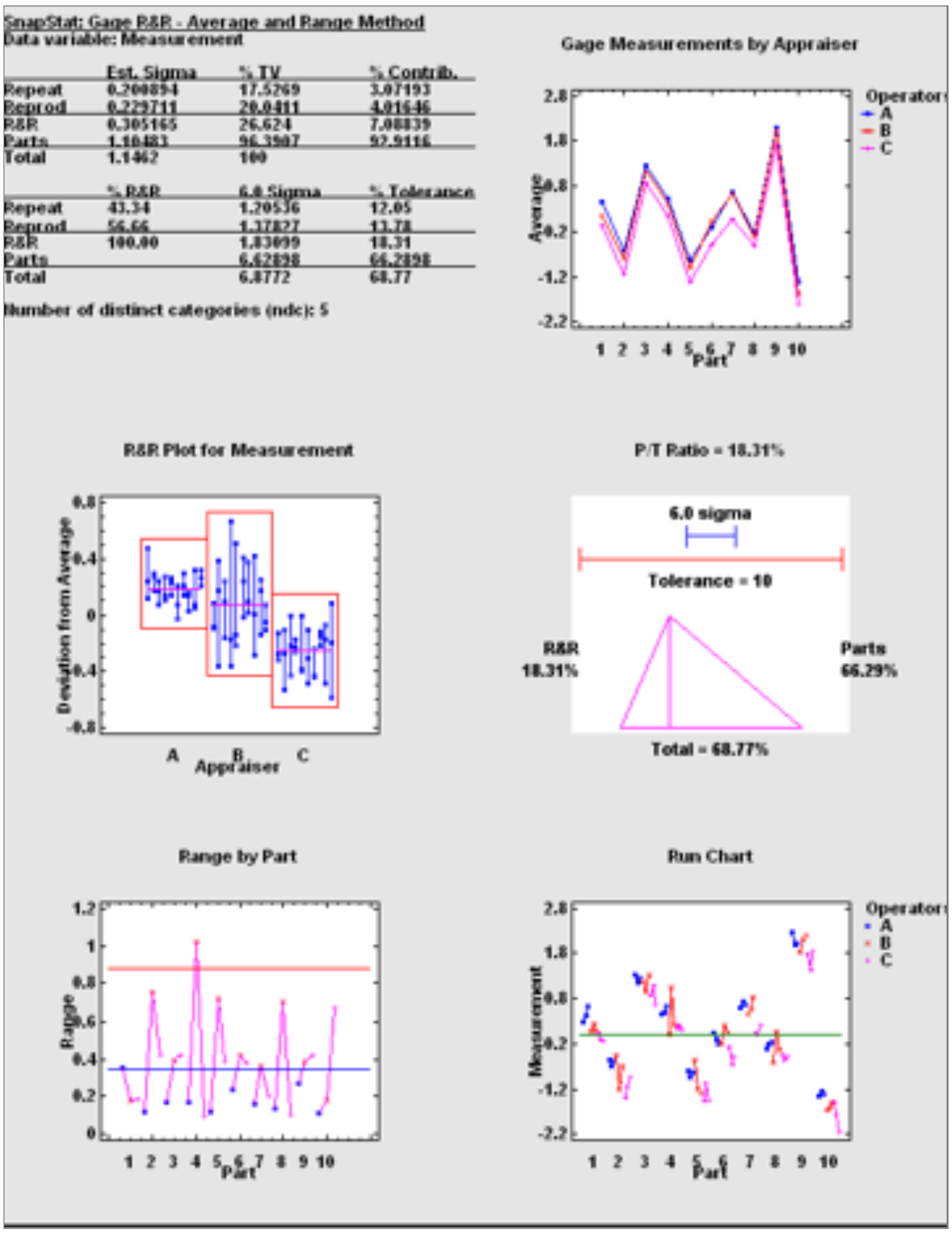
2. Measurement Systems Analysis (Gage Studies)

When implementing any statistical method that relies on data, it is important to be sure that the systems that collect that data are both accurate and precise. A set of procedures, often referred to as "Gage Studies", are widely used to assess the quality of measurement systems.

Variable Measurement Systems - Repeatability and Reproducibility

For measurement systems that result in quantitative measurements such as weight, concentration, or strength, it is important to determine the magnitude of any error in the resulting measurements. If the error is large, it may be impossible to determine whether or not an individual sample is within spec. In addition, designed experiments rely on the ability to separate real effects of making changes from the background noise and could be sabotaged by an inadequate measurement system

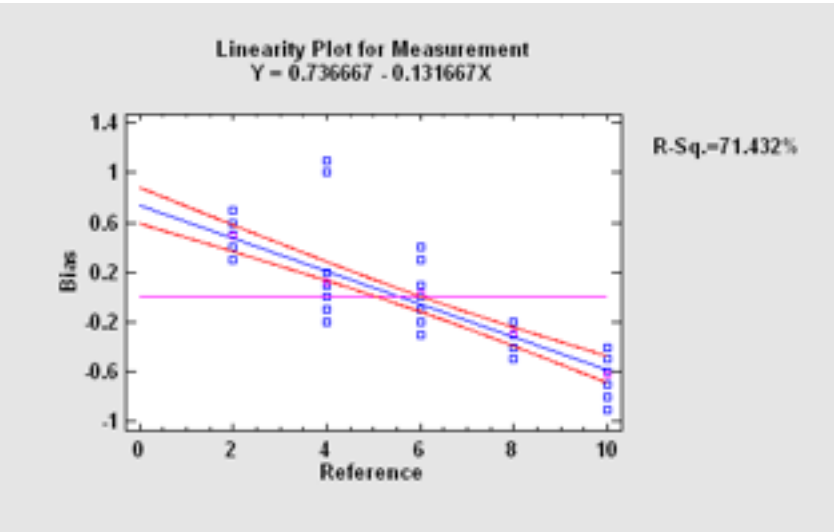
When quantifying measurement error, it is common to separate the error into repeatability (error due to the instrument or measurement procedure) and reproducibility (error due to the appraiser). STATGRAPHICS implements the procedures suggested by the AIAG (Automotive Industry Action Group), including the *average and range method*, *ANOVA method* (with and without interaction), and the *range method* (for short studies).



More: Gage Study Setup.pdf, Gage R&R SnapStat.pdf, Gage Studies - ANOVA Method.pdf, Gage Studies - Average and Range Method.pdf, Gage Studies - Range Method.pdf

Variable Measurement Systems - Linearity and Accuracy

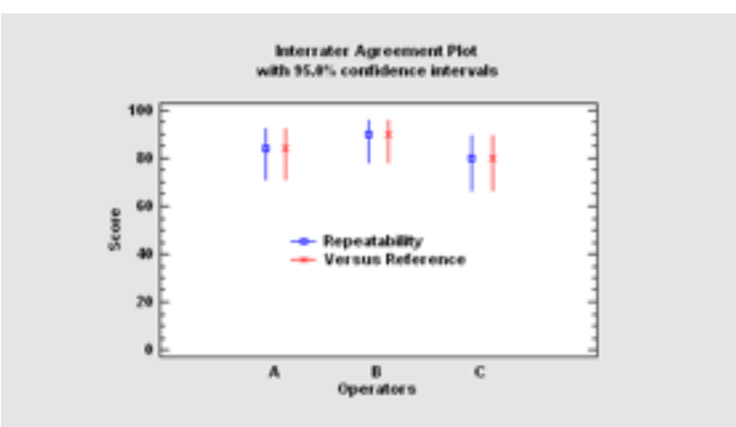
While repeatability and reproducibility studies concentrate on the variability or precision of a measurement system, *Linearity and Accuracy* studies quantify the bias. In these studies, multiple measurements are made on reference samples and an equation is constructed for the bias of the measurements.



More: Gage Linearity and Accuracy.pdf

Attribute Measurement Systems

When the results of a measurement system are PASS or FAIL rather than a quantitative value, special procedures are necessary. STATGRAPHICS Centurion provides three procedures outlined by the AIAG to deal with such systems: the *risk analysis method*, the *signal theory method*, and the *analytic method*. In the risk analysis method, multiple appraisers measure samples with known characteristics. Statistics are calculated based on how often the appraisers correctly characterize each sample and how frequently they agree with themselves and each other.



More: Gage Studies - Analytic Method.pdf, Gage Studies - Risk Analysis Method.pdf, Gage Studies - Signal Theory Method.pdf

3. Process Capability Analysis

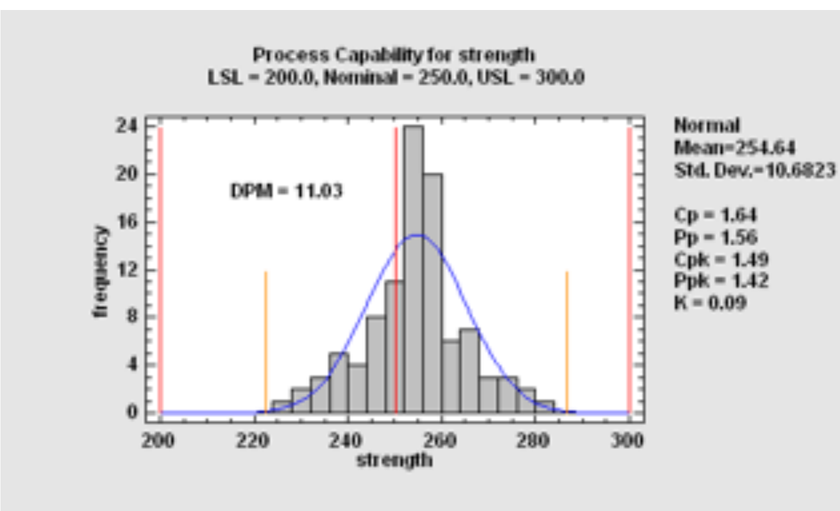
An important technique used to determine how well a process meets a set of specification limits is called a *process capability analysis*. A capability analysis is based on a sample of data taken from a process and usually produces:

1. An estimate of the ***DPMO*** (defects per million opportunities).
2. One or more ***capability indices***.
3. An estimate of the ***Sigma Quality Level*** at which the process operates.

STATGRAPHICS provides capability analyses for the following cases:

Capability Analysis for Measurement Data from a Normal Distribution

This procedure performs a capability analysis for data that are assumed to be a random sample from a normal distribution. It calculates capability indices such as Cpk, estimates the DPM (defects per million), and determines the sigma quality level (SQL) at which the process is operating. It can handle two-sided symmetric specification limits, two-sided asymmetric limits, and one-sided limits. Confidence limits for the most common capability indices may also be requested.

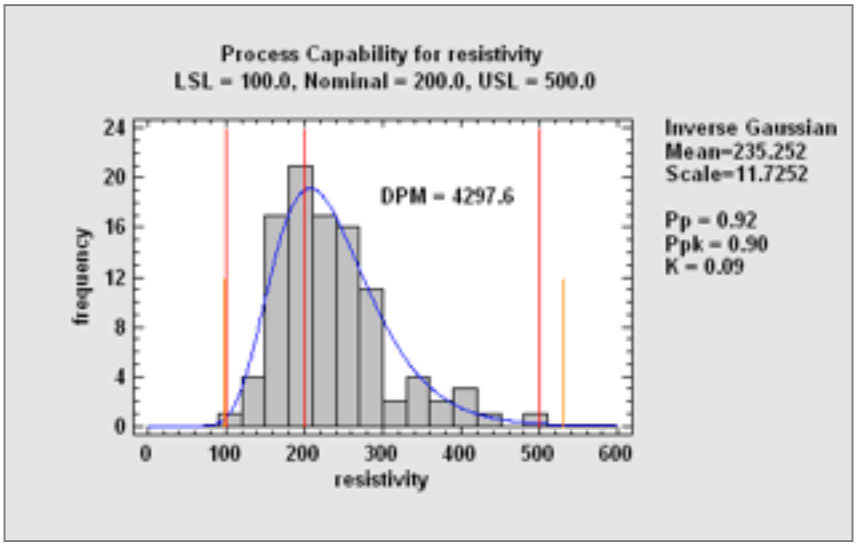


More: Capability Assessment SnapStat.pdf

Six Sigma Toolbox

Capability Analysis for Measurement Data from Non-Normal Distributions

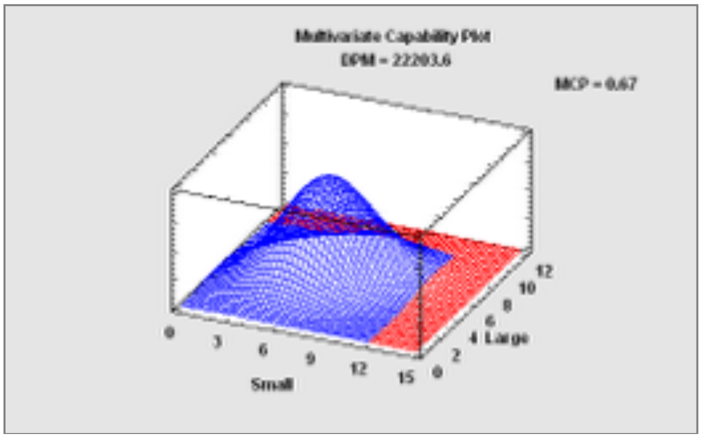
This procedure performs a capability analysis for data that are not assumed to come from a normal distribution. The program will fit up to 25 alternative distributions and list them according to their goodness-of-fit. For a selected distribution, it then calculates equivalent capability indices, DPM, and the SQL.



More: Capability Analysis (Variable Data).pdf

Capability Analysis for Correlated Measurements

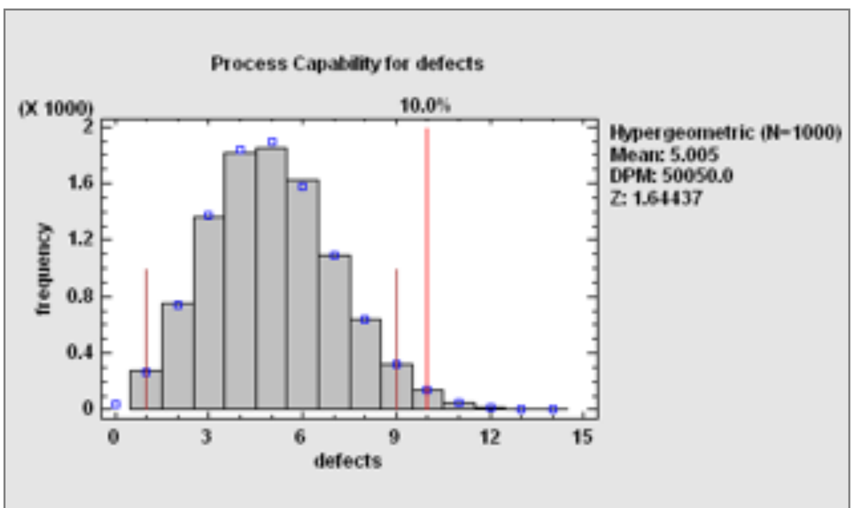
When the variables that characterize a process are correlated, separately estimating the capability of each may give a badly distorted picture of how well the process is performing. In such cases, it is necessary to estimate the *joint probability* that one or more variables will be out of spec. This requires fitting a multivariate probability distribution. This procedure calculates capability indices, DPM, and the SQL based on a multivariate normal distribution



More: Multivariate Capability Anaysis.pdf

Capability Analysis for Counts or Proportions

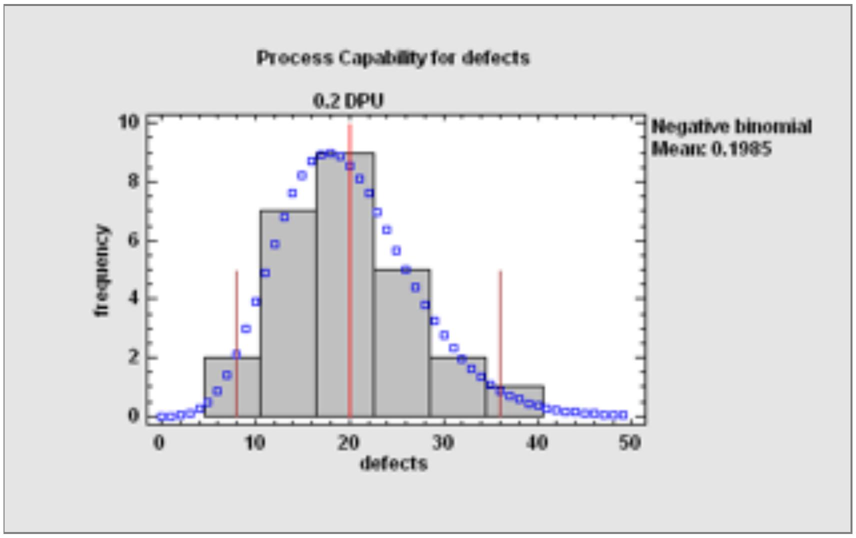
When examination of an item or event results in a PASS or FAIL rather than a measurement, the capability analysis must be based on a discrete distribution. For very large lots, the relevant distribution is the binomial. For small lots or cases of limited opportunities for failure, the hypergeometric distribution must be used



More: Capability Analysis (Percent Defective).pdf

Capability Analysis for Rates

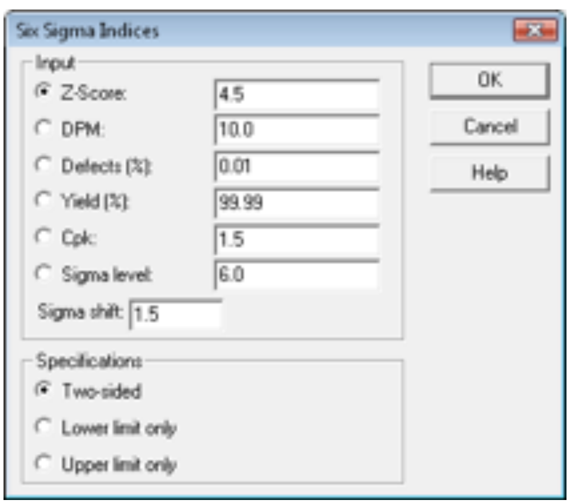
When the relevant measure of performance is a *rate*, then the capability analysis is based on: a Poisson distribution if failures occur randomly; a negative binomial distribution if failures tend to occur in clumps.



More: Capability Analysis (Defects per Unit).pdf

Six Sigma Calculator

The STATGRAPHICS *Six Sigma Calculator* converts between various commonly used quality metrics. After entering the value of any one metric, the equivalent values of the others are calculated.



More: Six Sigma Calculator.pdf

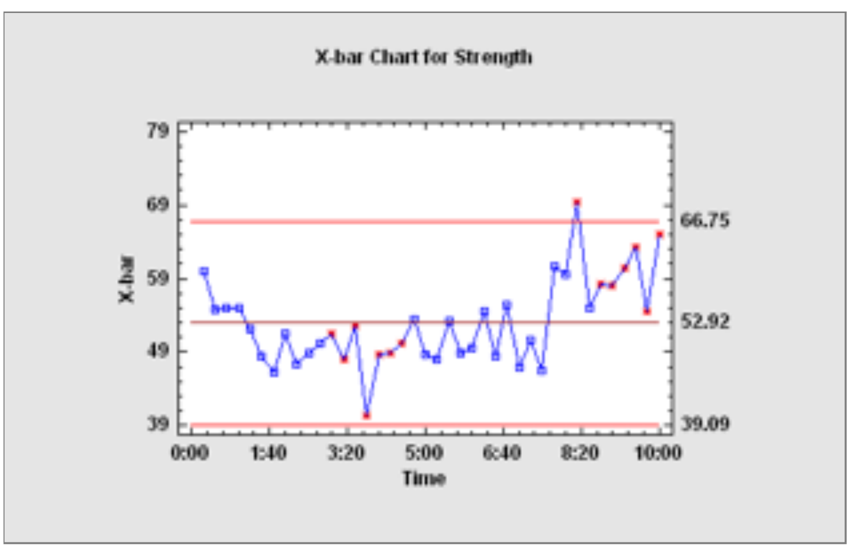
4. Statistical Process Control Charts

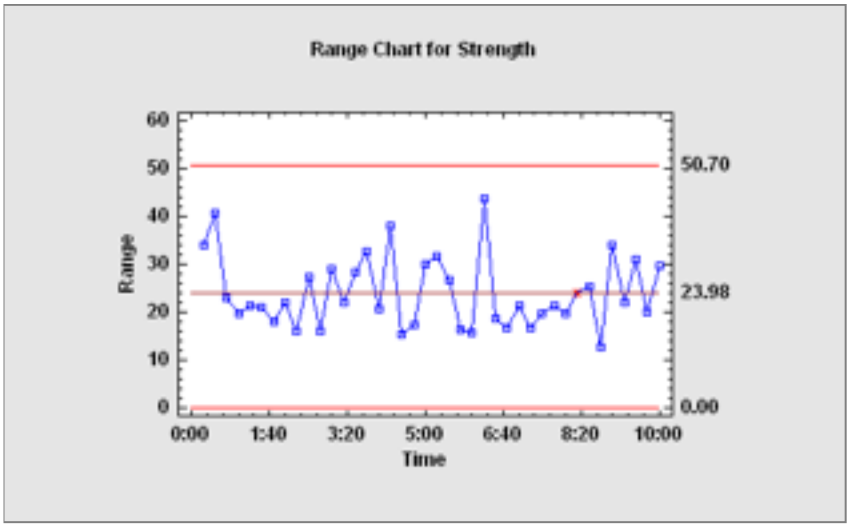
One of the most important actions that can help maintain the quality of any good or service is to collect relevant data consistently over time, plot it, and examine the plots carefully. All statistical process control charts plot data (or a statistic calculated from data) versus time, with control limits designed to alert the analyst to events beyond normal sampling variability.

STATGRAPHICS Centurion provides one of the most extensive collection of control charts available. All control charts can be used for *Phase I studies*, in which the data determine the location of the control limits, and *Phase II studies*, in which the data are compared against a pre-established standard. A special procedure is also provided to help design a control chart with acceptable power. E-mail alerts can be generated when points fall outside the control limits or when a runs rule is violated.

Basic Variables Charts

The classical type of control chart, originally developed back in the 1930's, is constructed by collecting data periodically and plotting it versus time. If more than one data value is collected at the same time, statistics such as the mean, range, median, or standard deviation are plotted. Control limits are added to the plot to signal unusually large deviations from the centerline, and runs rules are employed to detect other unusual patterns.

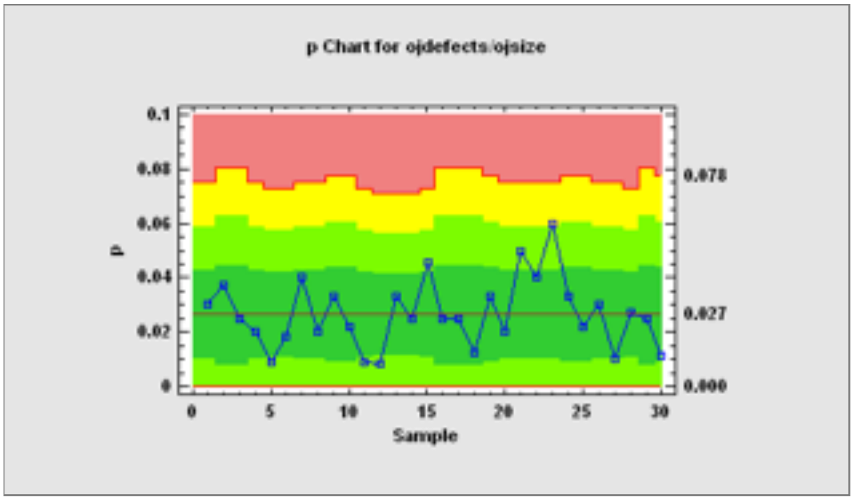




More: X-Bar and R Charts.pdf, X-Bar and S Charts.pdf, X-Bar and S-Squared Charts.pdf, Median and Range Charts.pdf, Individuals Control Charts.pdf

Basic Attributes Charts

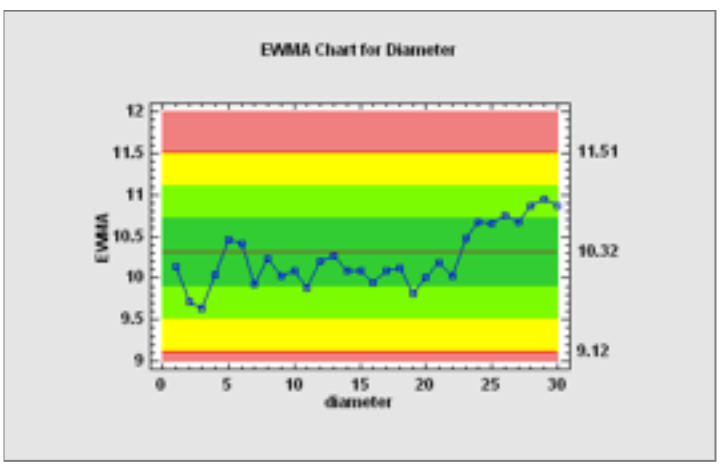
For attribute data, such as arise from PASS/FAIL testing, the charts used most often plot either rates or proportions. When the sample sizes vary, the control limits depend on the size of the samples. On most control charts, colored zones may be used to indicate the distance to 1, 2, and 3-sigma.



More: P Chart.pdf, NP Chart.pdf, U Chart.pdf, C Chart.pdf, U' Chart.pdf, P' Chart.pdf

Moving Average and EWMA Charts

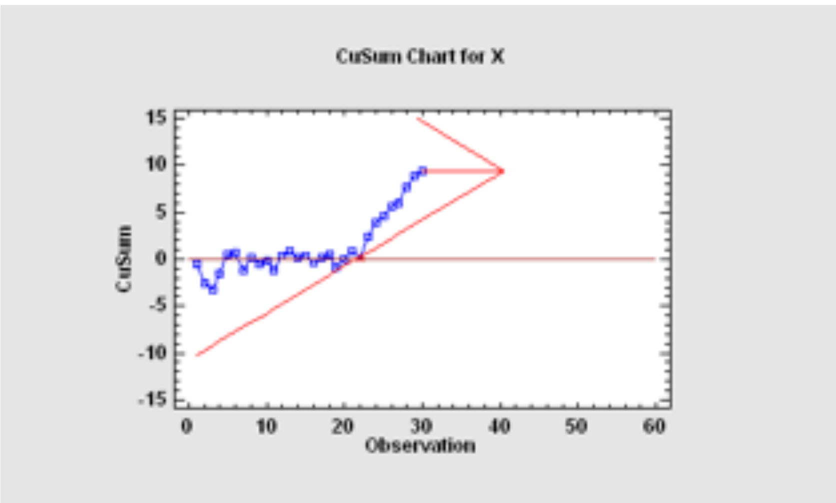
When data are collected one sample at a time and plotted on an individuals chart, the control limits are usually quite wide, causing the chart to have poor power in detecting out-of-control situations. This can be remedied by plotting a weighted average of the data instead of just the most recent observation. The most common "time-weighted" charts are the moving average (MA) chart and the exponentially weighted moving average (EWMA). The average run length of such charts is usually much less than that of a simple X chart.



More: Moving Average (MA) Charts.pdf , EWMA Charts.pdf

Cusum Charts

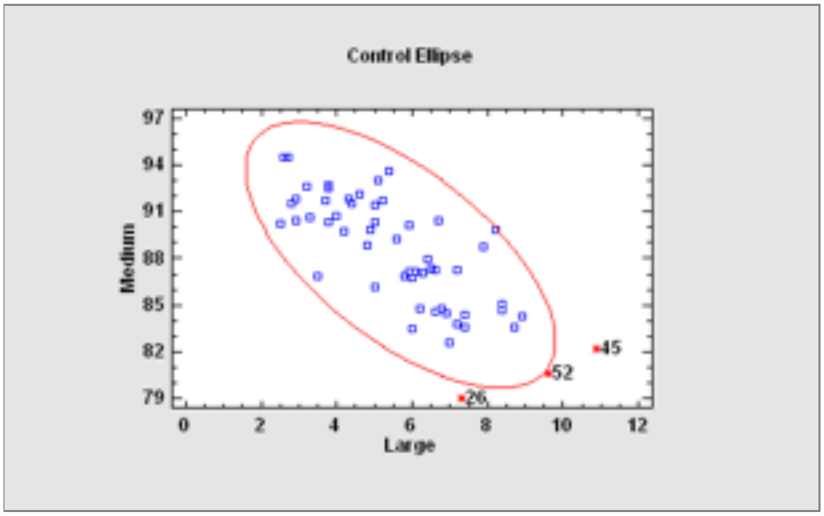
A useful chart for plotting measurements from a continuous process is the CUSUM chart, which plots at each time point the sum of all deviations from a target value up to and including the most recent observation. When the "V-mask" format for a Cusum chat is used, the process is deemed to be in control if all points on the chart fall within the mask. If any points fall outside the mask, as in the chart at the left, then an out-of-control alert is generated.



More: Cusum Charts (V-Mask).pdf , Cusum Charts (Tabular).pdf

Multivariate Control Charts

When data for more than one variable are collected, separate control charts are frequently plotted for each variable. If the variables are correlated, this can lead to missed out-of-control signals. For such situations, STATGRAPHICS provides several types of multivariate control charts: *T-Squared charts*, *Generalized Variance charts*, and *Multivariate EWMA charts*. In the case of two variables, the points may be plotted on a control ellipse.

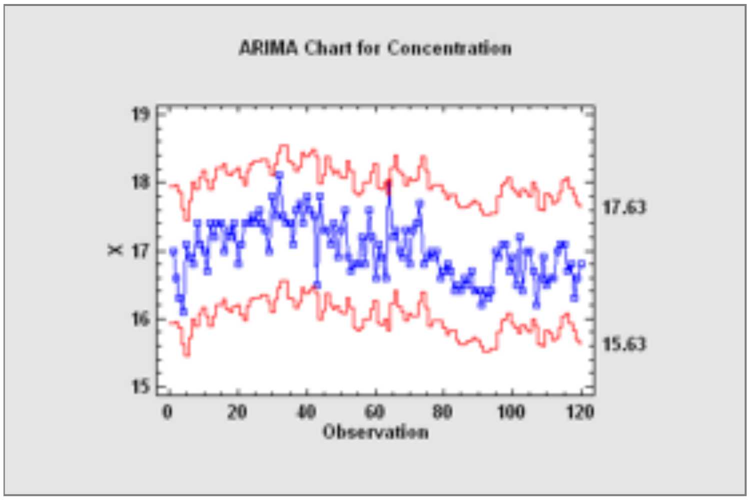


More: Multivariate T-Squared Control Chart.pdf, Multivariate EWMA Control Chart.pdf

ARIMA Control Charts

With today's automated data collection systems, samples are frequently collected at closely spaced increments of time. Any sort of process dynamics introduces correlation into successive measurements, which causes havoc with standard control charts that assume independence between successive samples. In such cases, a control chart that captures the dynamics of the process must be used to properly detect unusual events when they occur.

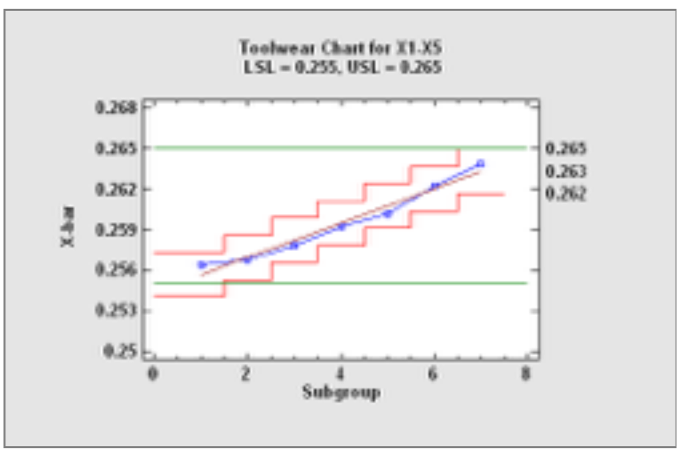
The proper chart for such situations is an *ARIMA control chart,* which is based upon a parametric time series model for process dynamics. Such charts either plot the residual shocks to the system at each time period, or they display varying control limits based upon predicted values one period ahead in time.



More: ARIMA Charts.pdf

Toolwear Charts

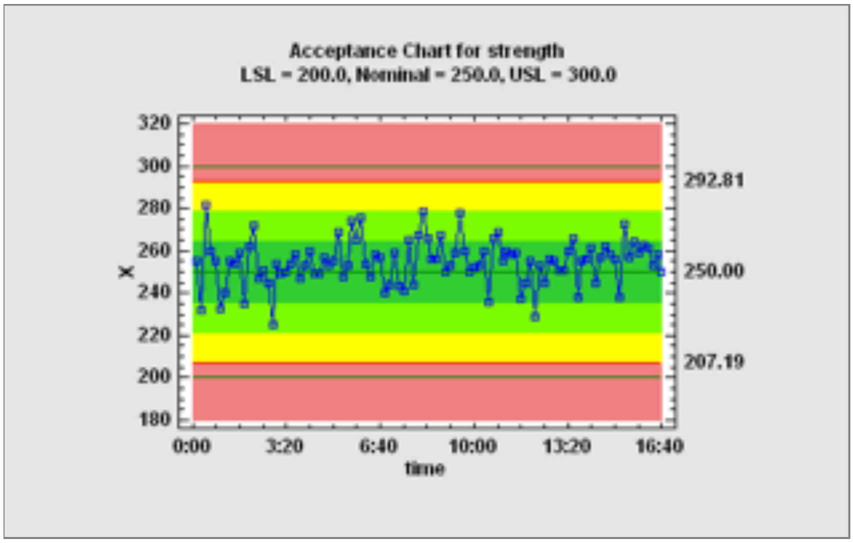
Control charts can also be used to monitor processes in which the mean measurement is expected to change over time. This commonly occurs when monitoring the wear on a tool, but also arises in other situations. The control charts for such cases have a centerline and control limits that follow the expected trend.



More: Toolwear Charts.pdf

Acceptance Control Charts

For processes with a high Cpk, requiring the measurements to remain within 3 sigma of the centerline may be unnecessarily restrictive. In such cases, the process may be allowed to drift, as long as it does not come too close to the specification limits. A useful type of control chart for this case is the *Acceptance Control Chart*, which positions the control limits based on the specification limits rather than the process mean.

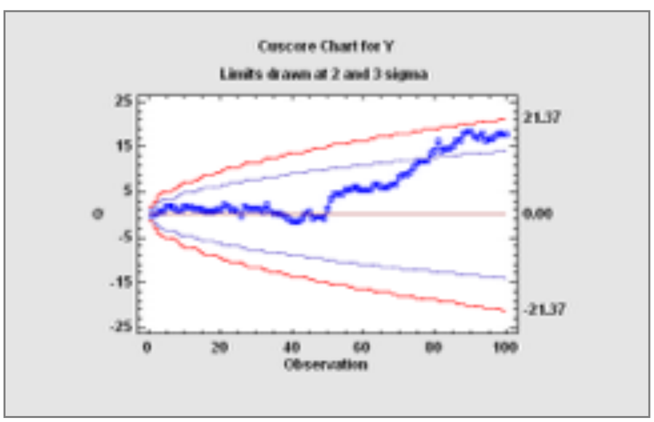


More: Acceptance Charts.pdf

Cuscore Charts

When monitoring a real-world process, the types of out-of-control situations that are likely to occur may be known ahead of time. For example, a pump that begins to fail may introduce an oscillation into the measurements at a specific frequency. In such cases, specialized *CuScore Charts* may be constructed to watch for that specific type of failure.

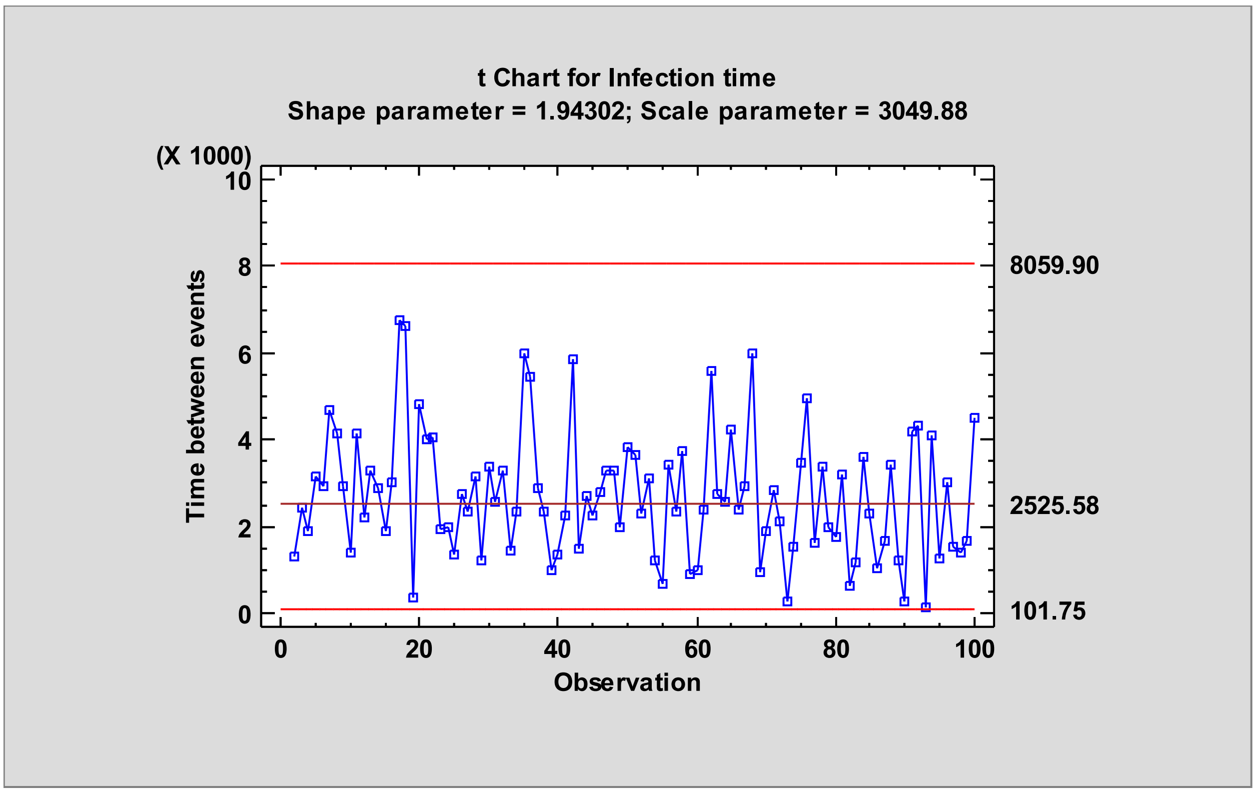
STATGRAPHICS will construct CuScore charts to detect: spikes, ramps, bumps of known duration, step changes, exponential increases, sine waves with known frequency and phase, or any custom type of pattern that the user wishes to specify.



More: Cuscore Charts.pdf

Control Charts for Rare Events

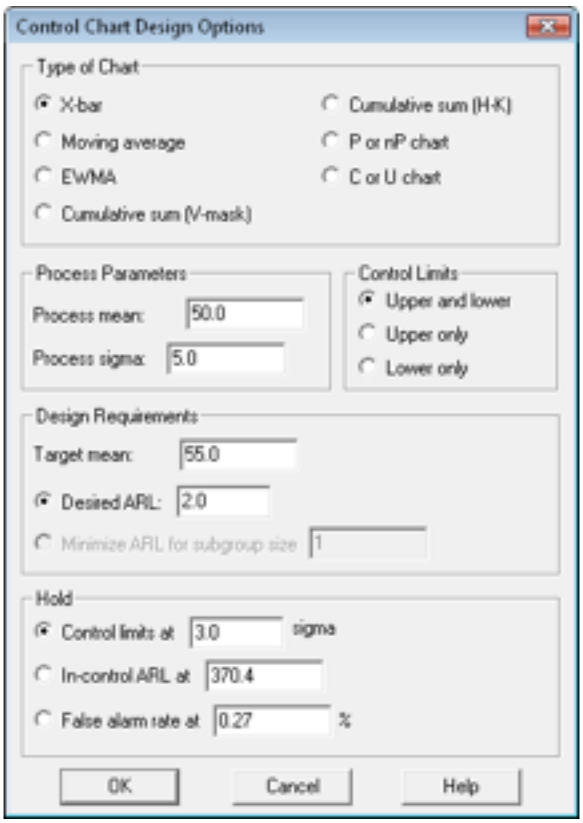
G charts and T charts are used to monitor the occurrence of rare events, such as infections in a hospital. By monitoring the length of time between consecutive events, the charts can detect changes in the underlying rate.



More: G Charts.pdf, T Charts.pdf

Control Chart Design

For a control chart to be effective, it must be able to distinguish between situations in which the process is operating as expected and situations in which it has deviated seriously from its target values. STATGRAPHICS provides a procedure for designing control charts that will detect deviations of a specified magnitude within an acceptable time. In a typical application, the user specifies a target mean and the desired average run length before a deviation of that magnitude is detected.

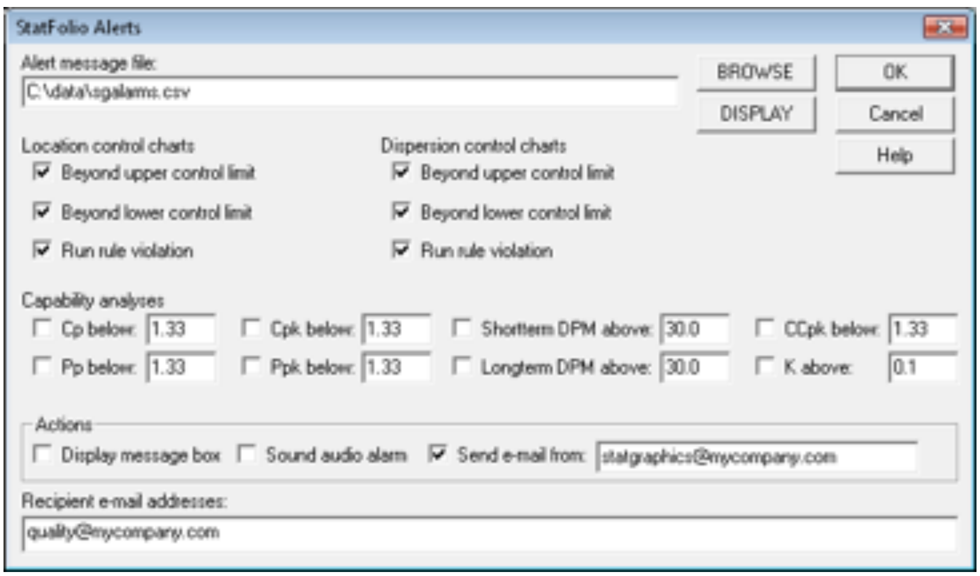


The procedure then determines the number of samples and/or smoothing parameter that will achieve the desired performance.

More: Control Chart Design.pdf

E-mail Alerts

The control chart procedures can be automated using the dynamic updating capabilities of Statgraphics Centurion. In such cases, it can be useful to generate e-mail alerts whenever an unusual event occurs. Alerts may be created when points on the control charts fall outside the control limits, or when a run rule is violated. If specification limits exist for the variable being plotted, alerts may also be generated whenever estimated capability indices fall below a threshold value or when the estimated DPM is too large.



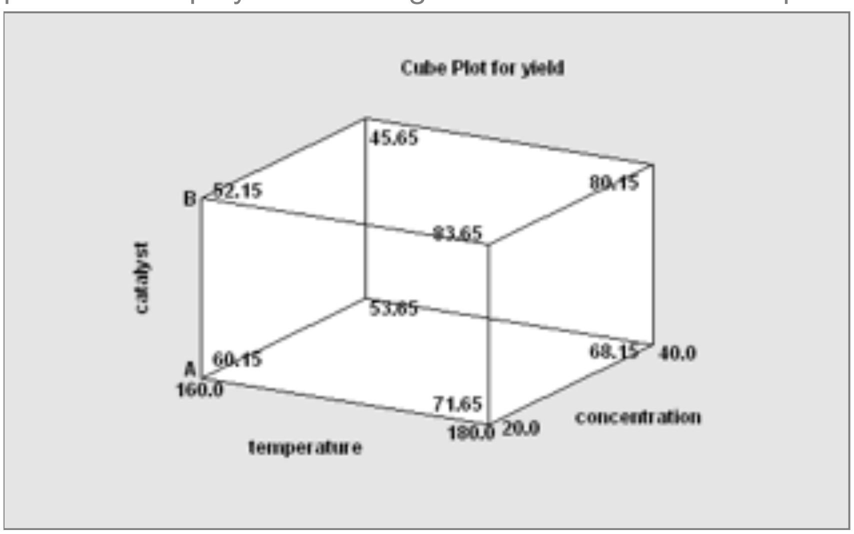
More: StatFolio Alerts.pdf

5. Design of Experiments

STATGRAPHICS contains extensive capabilities for the creation and analysis of statistically designed experiments. The designs that can be created are divided into several types.

Screening Designs

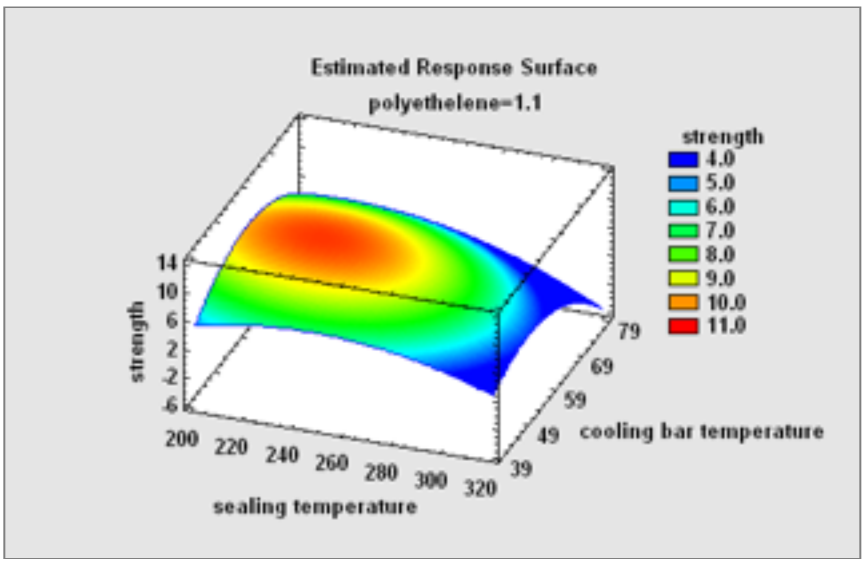
Screening designs are intended to determine the most important factors affecting a response. Most of the designs involve only 2 levels of each factor. The factors may be quantitative or categorical. Included are *2-level factorial* designs, *mixed level factorial* designs, *fractional factorials*, *irregular fractions*, and *Plackett-Burman* designs. For designs of less than full resolution, the confounding pattern is displayed. Blocking and randomization are options.



More: DOE Wizard - Screening Designs.pdf

Response Surface Designs

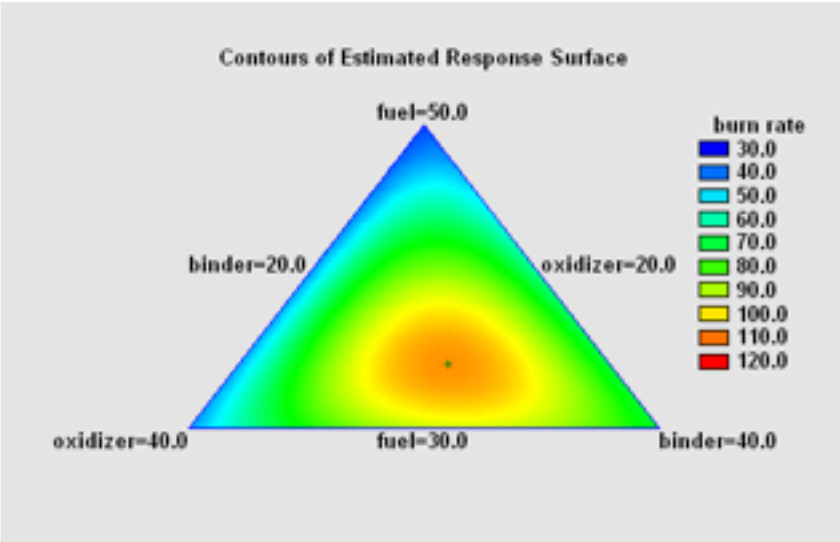
Response surface designs are intended to determine the optimal settings of the experimental factors. The designs involve at least 3 levels of the experimental factors. Included are *central composite* designs*, Box-Behnken* designs, *3-level factorials*, and *Draper-Lin* designs.



More: DOE Wizard - Response Surface Designs.pdf

Mixture Experiments

Mixture experiments involve components of a mixture, where the levels of the components are constrained to sum to 100% (or some other fixed value). Upper and lower constraints may be specified for each component. Included are *simplex-lattice*, *simplex-centroid*, and *extreme vertices* designs.



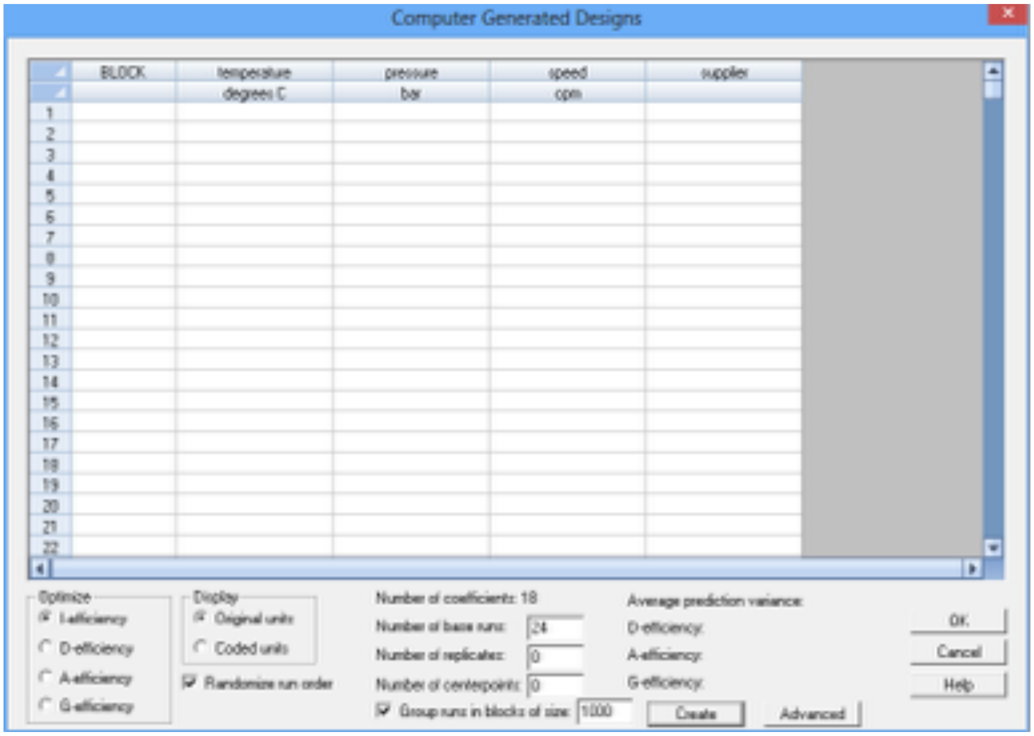
More: DOE Wizard - Mixture Experiments.pdf

Computer-Generated Optimal Designs

Computer-generated designs may be created given:

1. A statistical model to be fit.
2. The desired number of runs.
3. The optimality criterion to be maximized (A-efficiency, D-efficiency, G-efficiency, or I-efficiency).
4. Constraints that may exist limiting the combinations of factor levels at which experimentation is possible.

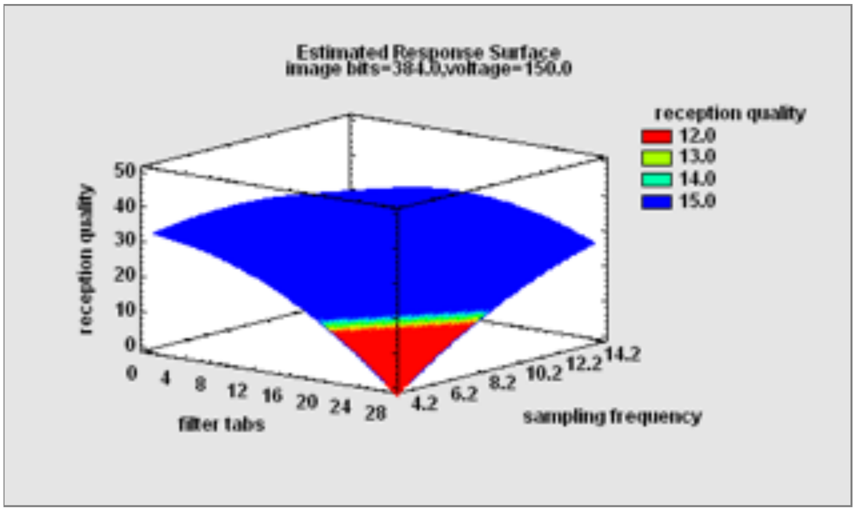
These designs are commonly used when the number of runs must be as small as possible, when the design region is constrained, or when additional runs need to be added to an undesigned experiment to improve its statistical properties.



More: DOE Wizard – Computer-Generated Designs.pdf, DOE Wizard - Multilevel Factorial Designs.pdf

Robust Parameter Designs

Statgraphics can create experimental designs for use in robust parameter design (RPD). In such experiments, two types of factors are varied: *controllable factors* that the experimenter can manipulate both during the experiment and during production, and *noise factors* that can be manipulated during the experiment but are normally uncontrollable. The goal of RPD is to find levels of the controllable factors where the response variables are relatively insensitive to changes in the noise factors.

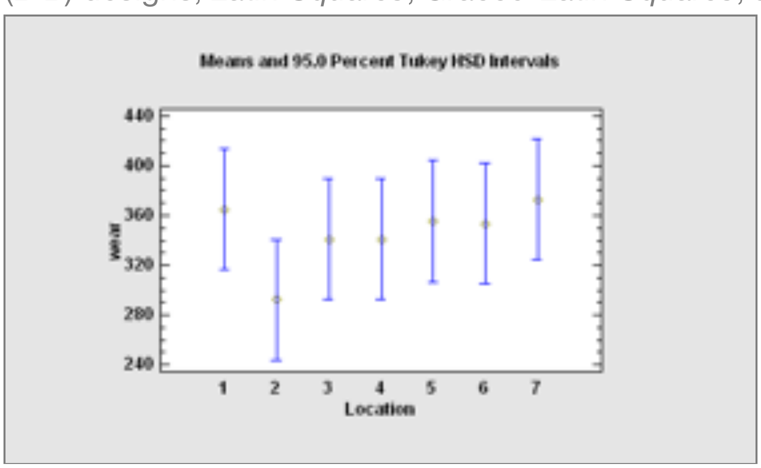


RPD designs may be created using either the crossed approach of Taguchi (with inner and outer arrays) or the combined approach of Montgomery (both types of factors varied in a single array).

More: DOE Wizard - Robust Parameter Designs.pdf

Single Factor Categorical Designs

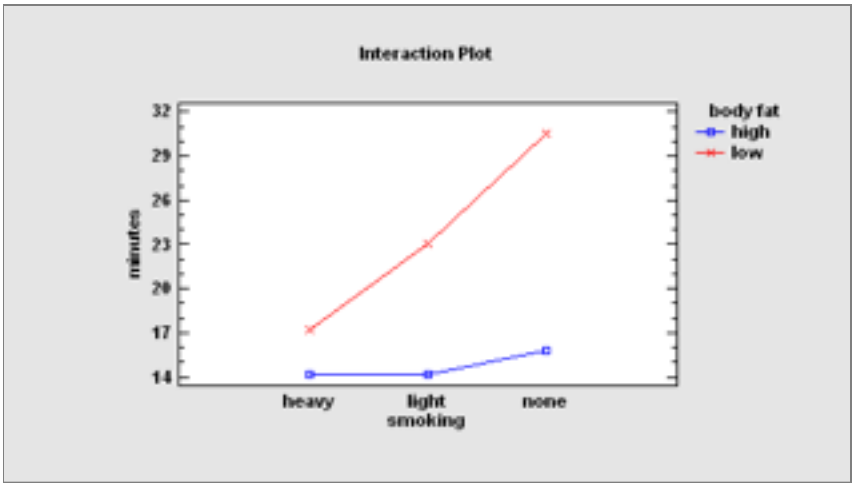
Single Factor Categorical designs are used to compare levels of a single non-quantitative factor. They include *completely randomized* designs, *randomized block* designs, *balanced incomplete block* (BIB) designs, *Latin Squares*, *Graeco-Latin Squares*, and *hyper-Graeco-Latin Squares*



More: DOE - Single Factor Categorical Designs.pdf

Multi-Factor Categorical Designs

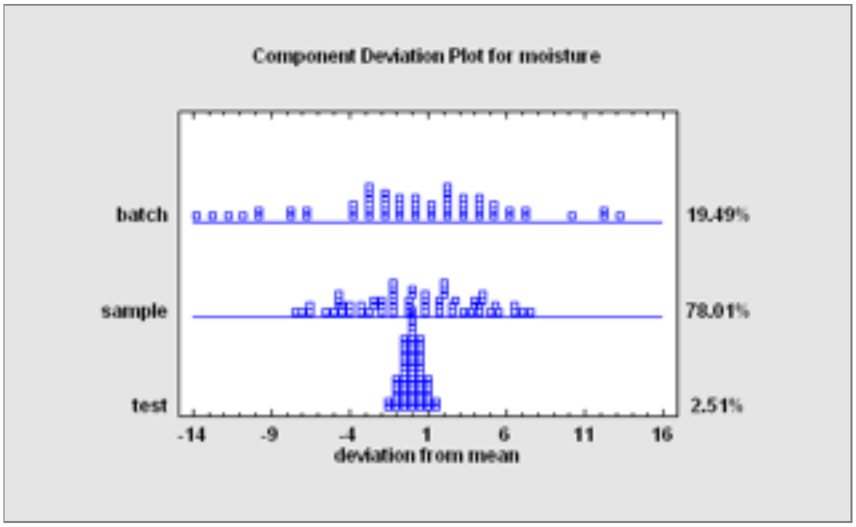
Multi-Factor Categorical designs are used to study multiple non-quantitative factors, with several levels of each. They are analyzed using a multifactor analysis of variance.



More: DOE - Multi-Factor Categorical Designs.pdf

Variance Component Designs

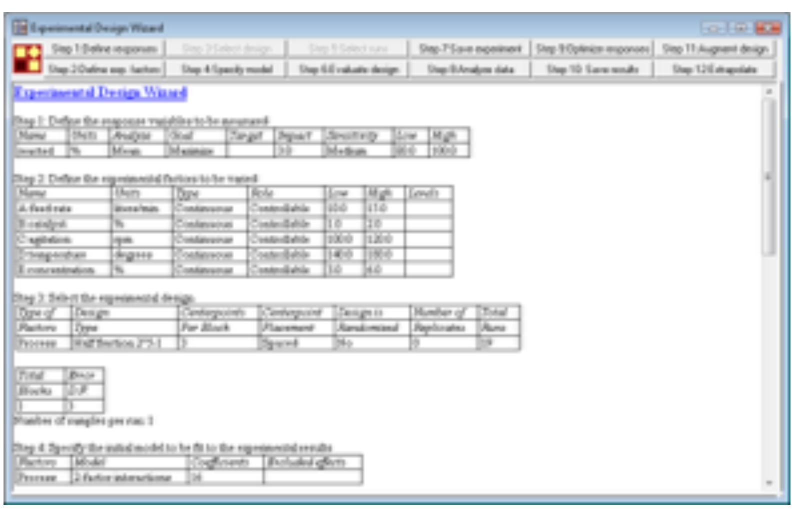
Variance Component (hierarchical) designs are used to study the effect of two or more nested factors on the variability of a response. Estimates of the contribution of each factor to the overall variability are obtained.



More: DOE - Variance Component Designs.pdf

Design of Experiments Wizard

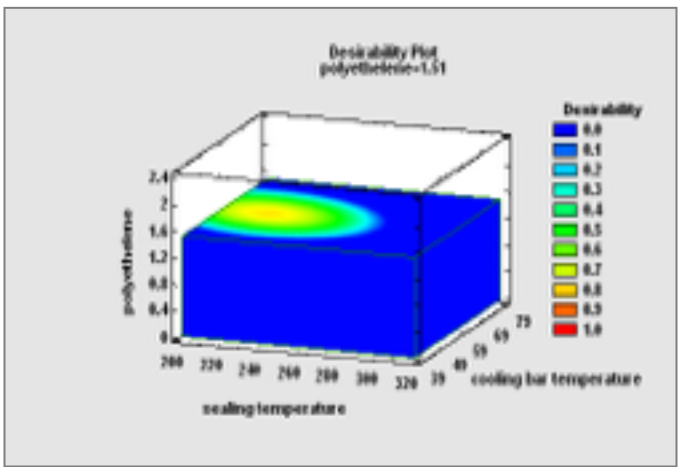
STATGRAPHICS Centurion contains a wizard that assists users in constructing and analyzing designed experiments. It guides the user through twelve important steps. The first 7 steps are executed before the experiment is run. The final 5 steps are executed after the experiment has been performed.



More: Design of Experiments Wizard.pdf

Multiple Response Optimization

In order to find a combination of the experimental factors that provides a good result for multiple response variables, the DOE Wizard uses the concept of *desirability functions*. Desirability functions provide a way to balance the competing requirements of multiple responses, which may be measured in different units. Users specify the target value or acceptable range for each response, together with its relative importance. The program then finds the best combination of the experimental factors.



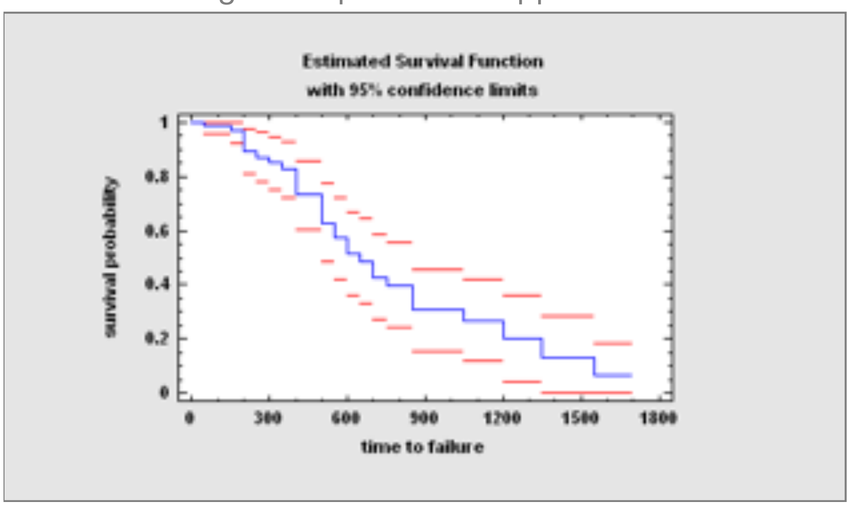
More: Design of Experiments Wizard.pdf

6. Life Data Analysis and Reliability

Determining the reliability of manufactured items often requires performing a life test and analyzing observed times to failure. Such data is frequently censored, in that some items being tested may not have failed when the test is ended. In addition, it may be necessary to accelerate failure times by changing the value of an influential variable such as temperature. For all of these reasons, special tools are needed to deal with this type of data.

Life Tables

In analyzing life data, interest commonly centers on estimating the probability that a unit will still be operating at any given time. A common way of estimating this survival function, without making any assumption about functional form or error distribution, is to tabulate the data and calculate the survivor function directly from the observed failures. When censoring is present, the estimates are calculated using the Kaplan-Meier approach.



More: Life Tables (Intervals).pdf, Life Tables (Times).pdf

Distribution Fitting with Censored Data

If sufficient data is available, it may be possible to fit a specific distribution to the failure times. Maximum likelihood methods can be easily adapted to the presence of censored data. STATGRAPHICS will automatically fit up to 45 probability distributions for any sample of data and rank them according to goodness-of-fit.

Comparison of Alternative Distributions

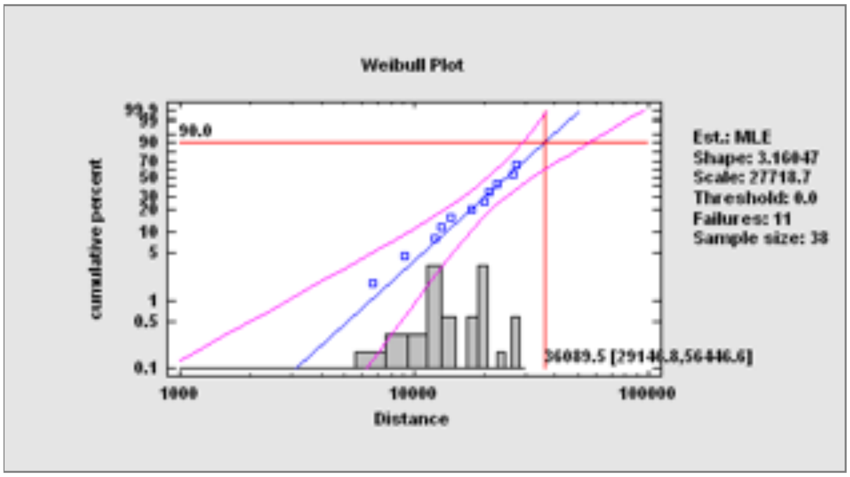
Distribution	*Est. Parameters*	*Log Likelihood*	*KSD*
Weibull	2	-404.991	0.0901357
Normal	2	-406.4	0.0903629
Logistic	2	-408.408	0.103344
Laplace	2	-413.516	0.108477
Smallest Extreme Value	2	-409.469	0.122783
Largest Extreme Value	2	-405.653	0.128409
Gamma	2	-404.845	0.128419
Loglogistic	2	-406.131	0.131113
Lognormal	2	-405.125	0.155015
Birnbaum-Saunders	2	-404.725	0.159099
Uniform	2	-400.338	0.159942
Inverse Gaussian	2	-404.796	0.16054
Exponential	1	-427.009	0.329046
Pareto	1	-510.249	0.448162

More: Distribution Fitting (Censored data).pdf

Weibull Analysis

Experience has shown that failure data can often be well modeled by a Weibull distribution. A common method to check the fit of a Weibull distribution is through a Weibull plot. Uncensored failure times should fall approximately along a straight line.

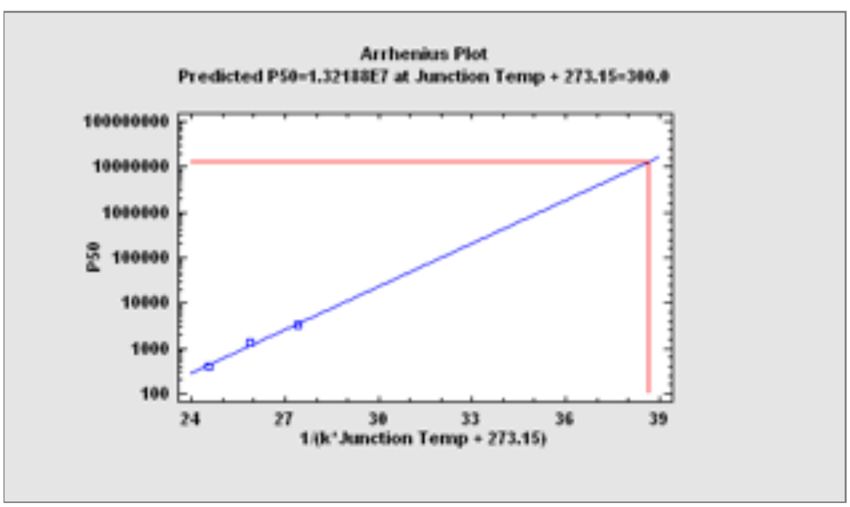
In the STATGRAPHICS *Weibull Plot,* you may add a histogram of censored failure times and confidence limits for failure percentiles.



More: Weibull Analysis.pdf

Arrhenius Plot

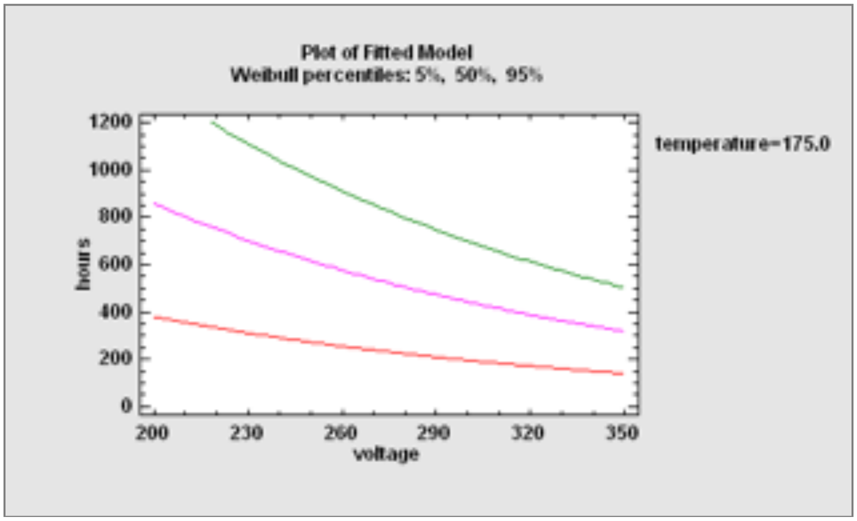
When failures do not occur often enough under normal operating conditions, it is necessary to accelerate the failures by increasing the stress caused by one or more variables. A very common accelerant is temperature. By analyzing failure rates at high temperatures and fitting an Arrhenius model, it is often possible to extrapolate the data back to a normal operating temperature (usually expressed in Kelvin).



Model: Arrhenius Plot.pdf

Life Data Regression

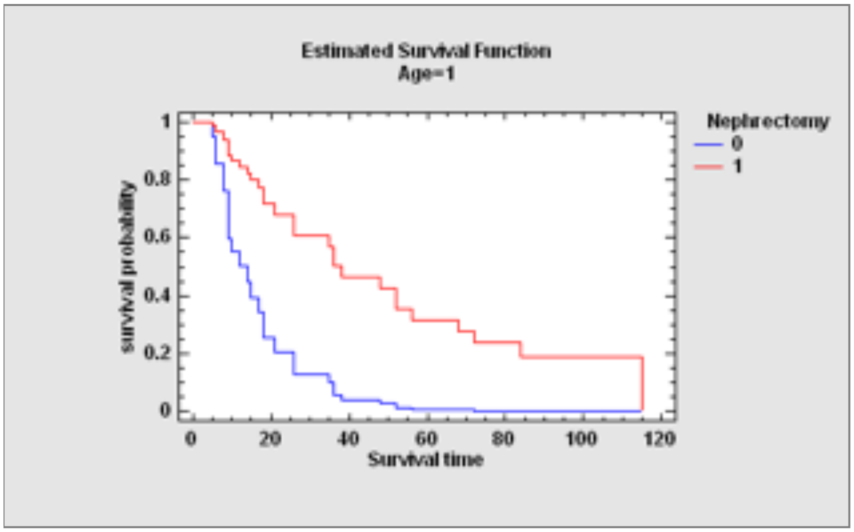
To describe the impact of external variables on failure times, regression models may be fit. Unfortunately, standard least squares techniques do not work well for two reasons: the data are often censored, and the failure time distribution is rarely Gaussian. For this reason, STATGRAPHICS provides a special procedure that will fit life data regression models with censoring, assuming either an exponential, extreme value, logistic, loglogistic, lognormal, normal or Weibull distribution.



More: Life Data Regression.pdf

Cox Proportional Hazards

The *Cox Proportional Hazards* procedure is an alternative method for fitting a life data regression without assuming any specific distributional form. Instead, it is assumed that the predictor variables affect the hazard function in a multiplicative manner. Like the parametric life data regression procedure, the predictor variables can be either quantitative or categorical.

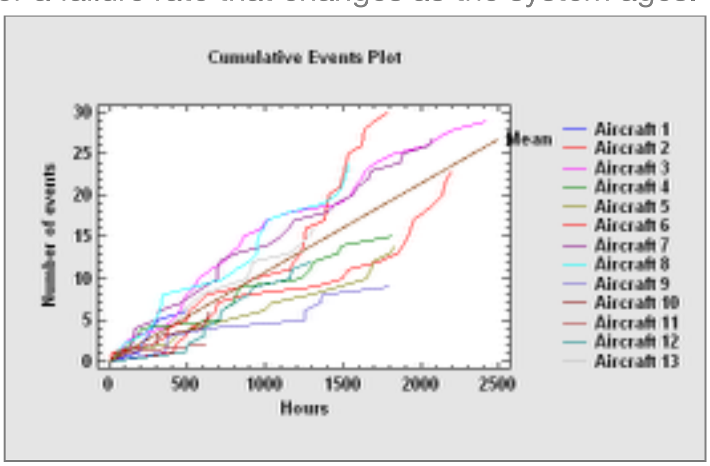


More: Cox Proportional Hazards.pdf

Analysis of Repairable Systems

The *Repairable Systems* procedures are designed to analyze data consisting of failure times from systems that can be repaired. It is assumed that when the system fails, it is immediately repaired and placed in service again. Further, it is assumed that the repair time is negligible compared to the time between failures. The goal of the analysis is to develop a model that can be used to estimate failure rates or quantities such as the MTBF (mean time between failures).

This procedure differs from the *Distribution Fitting* and *Weibull Analysis* procedures in that it allows for a failure rate that changes as the system ages.



More: Repairable Systems (Times).pdf, Repairable Systems (Intervals).pdf,

7. Acceptance Sampling

When lots containing a relatively large number of items require inspection, acceptance sampling plans can provide reasonable protection against shipping or receiving an unacceptable fraction of non-conforming items without inspecting 100% of the lot. The **Acceptance Sampling** procedures generate acceptance sampling plans by on either attributes or variables.

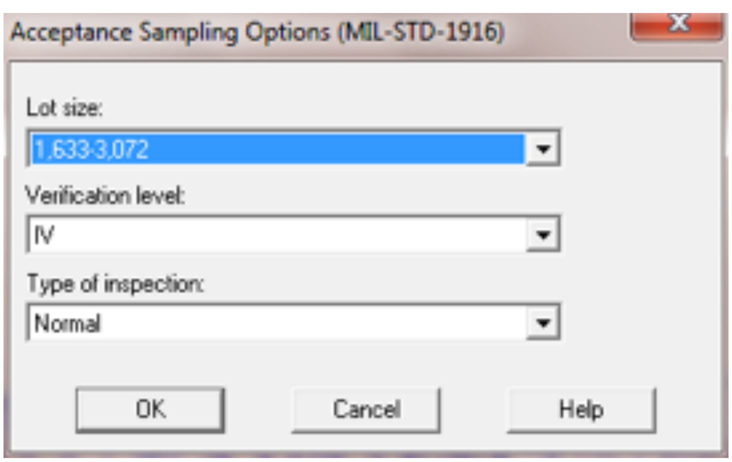
STATGRAPHICS generates several types of acceptance sampling plans:

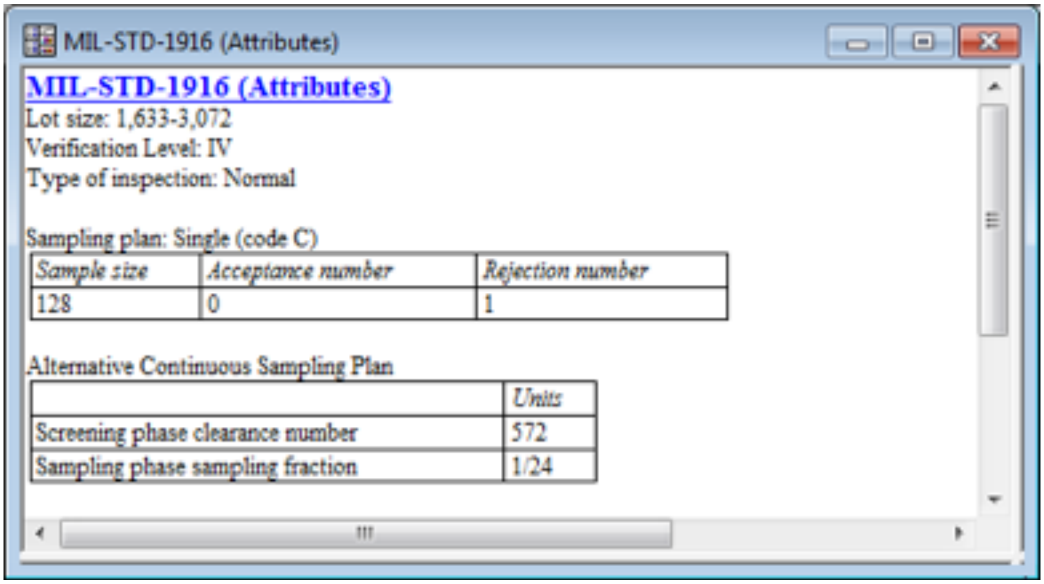
- **OC Plans** - plans that control the alpha and beta risks, i.e., the probability of accepting a bad lot and the probability of rejecting a good lot. For such a plan, “good” and “bad” must be well-defined.

- **AOQL Plans** - plans that minimize the average outgoing quality limit, i.e., the maximum fraction of non-conforming items accepted on average. Such a plan requires 100% inspection and rectification of all rejected lots.

- **LTPD Plans** - plans that minimize total inspection while controlling the risk of rejecting a bad lot, where “bad” must again be well-defined. Such a plan also requires 100% inspection and rectification of all rejected lots.

- **MIL-STD 105E, 414, and 1916** – plans developed by the U. S. Department of Defense and widely adopted by many companies.




MIL-STD-1916 (Attributes)

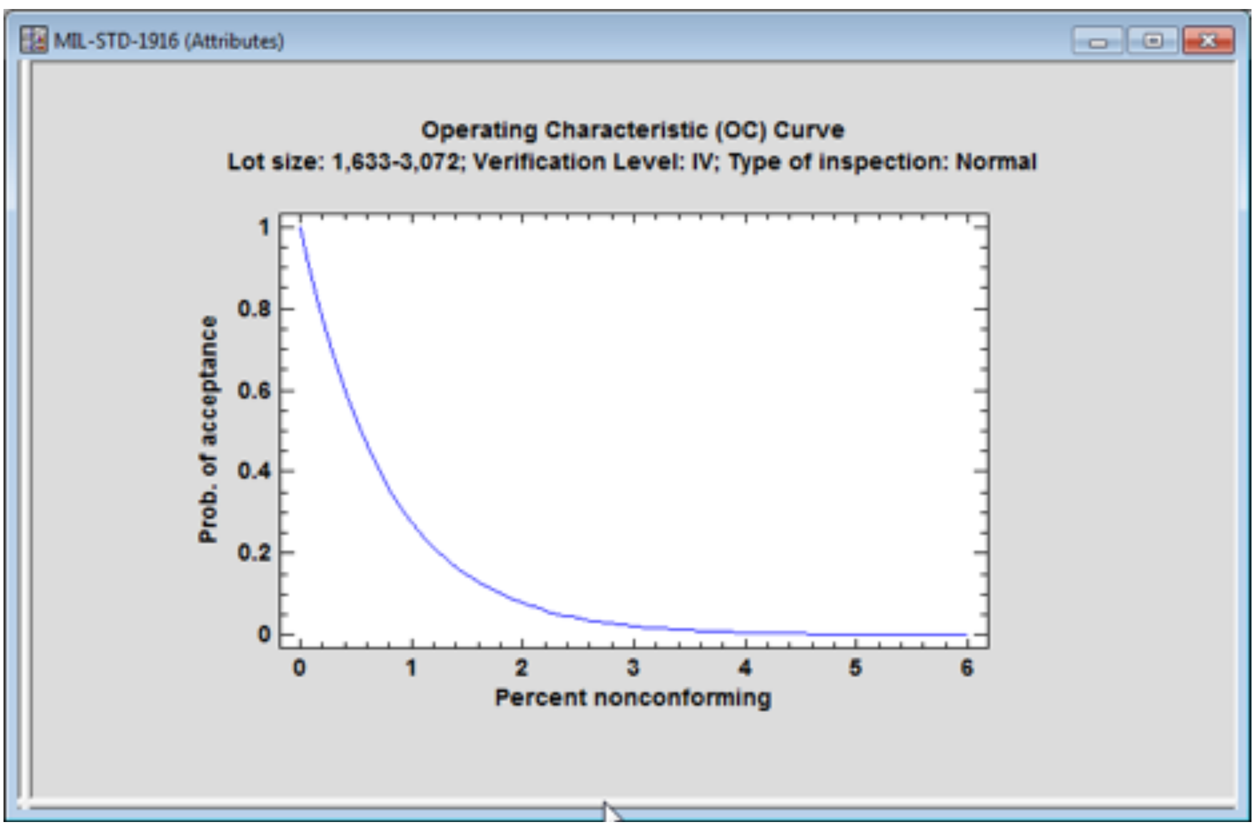
MIL-STD-1916 (Attributes)
Lot size: 1,633-3,072
Verification Level: IV
Type of inspection: Normal

Sampling plan: Single (code C)

Sample size	*Acceptance number*	*Rejection number*
128	0	1

Alternative Continuous Sampling Plan

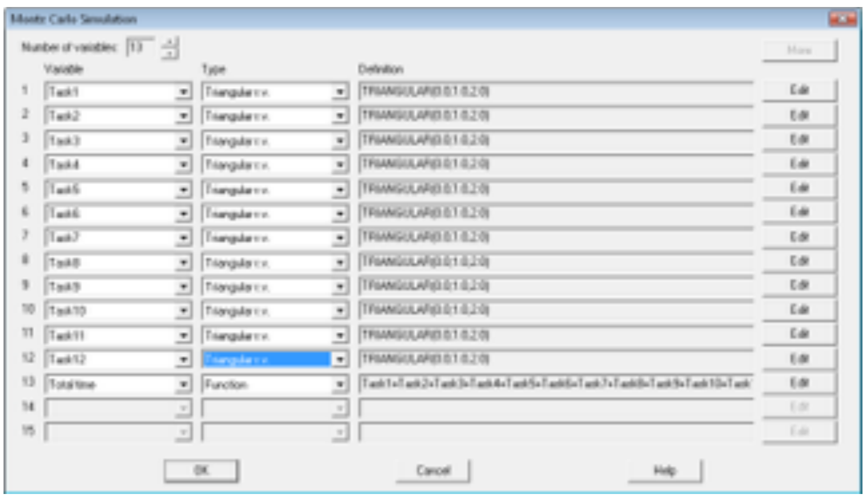
	Units
Screening phase clearance number	572
Sampling phase sampling fraction	1/24



8. Monte Carlo Simulation

Monte Carlo simulation is used to estimate the distribution of variables when it is impossible or impractical to determine that distribution theoretically. It is used in many areas, including engineering, finance, and DFSS (Design for Six Sigma). A typical Monte Carlo simulation includes:

1. One or more input variables X, some of which usually follow a probability distribution.
2. One or more output variables Y, whose distribution is desired.
3. A mathematical model coupling the X's and the Y's.



More: Monte Carlo Simulation.pdf