Objective Experiments Glossary of Statistical Terms

This glossary is intended to provide friendly definitions for terms used commonly in engineering and science. It *is not* intended to be absolutely precise.

α Statisitics: The probability of making a type I error. It is related to the confidence by confidence = (1 - α) x 100.
Reliability: The location parameter for a Weibull Distribution.

β Statistics: The probability of making a type II error. It is also called Power. This symbol is also sometimes used to indicate coefficients in a polynomial model.
Reliability: The shape parameter for a Weibull Distribution.

σ Statistics: The symbol for the true standard deviation. We can never know the true standard deviation because it is obscured by response variation, so it is a theoretical idea.
Reliability: The shape parameter for a Lognormal Distribution.

χ^2 A distribution used to make decisions about standard deviations.

$\chi^2_{Critical}$ A value from the χ^2 distribution used to compare with a computed χ^2 value in a χ^2 test.

χ^2 Test A test comparing a sample divided into at least three categories with a standard.

Alpha Statistics: The probability of making a type I error. It is related to the confidence by confidence = (1 - α) x 100.
Reliability: The location parameter for a Weibull Distribution.

Antagonism An interaction of factors producing a poorer response than anticipated by considering the factor levels independently.

Attribute Data Data that are not continuous. Attribute data fit into categories that can be described by numbers or words. Examples are Pass/Fail and Number of people residing in a home.

Attributes Control Chart A control chart for monitoring attribute data.

Average A term used to indicate either the mean or the median depending on the situation. Typically it refers to the mean in industrial contexts.

b-Coefficient A number that multiplies a term in a model to define the shape of the response surface.

Bathtub Curve A plot of the Hazard Rate for the life of a unit. Typically units have a higher hazard rate early in life due to defects, a flat and lower hazard rate through the middle of life, and an increasing hazard rate near the end of life, forming g a bathtub shape.

Bell-Shaped Pile of Data A normal shape for data to take when plotted on a histogram.

Beta Statistics: The probability of making a type II error. It is also called Power.
Reliability: The shape parameter for a Weibull Distribution.

Binomial Distribution A discrete distribution of pass-fail data that is applicable to reliability demonstrations.

Block A group of experimental trials.

Blocking A technique that breaks experiments into smaller groups of trials to eliminate the effect of a nuisance factor.

Blocking Factor A factor used to divide experimental trials into blocks for blocking.

Box-Behnken Design An experiment design for collecting data to fit a full quadratic model. Also called a "Face-Centered Cubic Design" or an "Interaction Plus Star Design."

Box-Cox Plot A plot of the log of the mean vs. the log of the standard deviation for replicate measurements. The slope of this line can help determine an appropriate transformation for data to make the standard deviation constant over the region of interest. The Box-Cox Transformation raises each response to the power of 1 minus the slope of this line.

Box-Cox Transformation A mathematical operation performed on responses to make the standard deviation of the transformed responses constant over the region of interest. The Box-Cox Transformation raises each response to the power of 1 minus the slope of the line in a Box-Cox Plot.

C_P A measure of process potential, it compares the process variation to specification limits.

C_{PK} A measure of process capability, it compares the process variation to the specification limits taking the process mean into account.

C_{PL} A measure of the process capability, it compares the process variation below the process average with the specification limit below the process average.

C_{PU} A measure of the process capability, it compares the process variation above the process average with the specification limit above the process mean.

C_R The reciprocal of C_{PK}.

CDF Cumulative Distribution Function. In reliability, the cumulative probability distribution of failing up until and in the next instant at any time t.

c-Chart An attribute control chart used to monitor the number of non-conformities in a unit.

Censored Data Reliability data that do not have precisely known failure times.

Center Point An experiment in which all factors are set to their middle value.

Central Composite Design An experiment design to collect data to fit a full quadratic model. The region of interest is spherical for this design.

Central Limit Theorem The theorem that states that the distribution of means approaches a normal distribution as the sample size approaches infinity. It allows us to assume Normal behavior for averages.

Coded Factors Factors can be coded to a different scale to improve numerical accuracy in calculations. A common coding for process factors is to to code the high level as +1 and the low level as -1 with intermediate values coded linearly over the range [-1,1].

Coded Responses Sometimes it is valuable to code responses to make it easier to find a Sweet Spot. For example, you can code your goal as 1, the unacceptable values as 0, and intermediate response values a linearly over the range [0, 1]. The Sweet Spot will have a maximum value for the coded response regardless of whether you are seeking a maximum, a minimum, or a number in a range. See also desireability.

Coding Changing a value to a different value, such as coding a high level as +1 and a low level as -1.

Combined s An estimate of the standard deviation for the region of interest formed by combining separate estimates of the standard deviation by a technique called pooling.

Combined Standard Deviation An estimate of the standard deviation for the region of interest formed by combining separate estimates of the standard deviation by a technique called pooling.

Common Cause An intrinsic cause of variation in a process. Variation which is part of a process when it is operating normally.

Confidence The percentage of times a good outcome is achieved when a technique is applied consistently.

Confidence Interval An interval between a lower and an upper limit in which the long-term mean should lie within the specified confidence.

Confidence Limits The lower and upper limits for a confidence interval.

Consistent Standard Deviation Estimates A term used to indicate that the standard deviation is constant over the region of interest.

Continuous Refers to the property of a factor or response that a level can be found between any two other levels, no matter how small the difference between these other levels.

Contour Plot A picture of a model that shows contour lines of constant response.

Control Chart A run chart with limits indicating the normal operation of a process. Typically these limits are ± 3 times the standard deviation.

Critical Value A value from a distribution to which a calculated value is compared in a significance test.

Cube A three-dimensional object that represents the region of interest for a 3-factor process factor experiment.

Cubic Model A polynomial model containing, at a minimum, a constant term, a term for each main effect, a term for each two-factor interaction between main effects, a term for the square of each main effect, and a term for each 3-factor interaction of the main effects. The full cubic model also includes terms for the interactions of each quadratic main effect with each linear main effect and terms for the cube of each main effect.

Cycle A periodic fluctuation, such as a temperature cycle.

D-Optimal Design An experiment design that minimizes the determinant of the variance-covariance matrix of the solution vector. The goal is to provide accurate and precise estimates of the b coefficients (or effects).

Degrees of Freedom The number of values which could be arbitrarily assigned. For example, if you want to assign data to the categories “pass” “fail high,” and “fail low,” the degrees of freedom is 2, because once data has been assigned to any 2 categories the remainder must be assigned to the third – it cannot be assigned arbitrarily.

Design Cube A three-dimensional object that represents the region for data collection for a 3-factor process factor experiment.

Desireability An indication of how well a response meets a goal. Typically desireability uses coded responses with 0 indicating that the goal is not met at all, 1 indicating that the goal was met perfectly, and intermediate values indicating that the goal is partially met. For multiple goals the overall desireability is typically calculated as the geometric mean of the individual desireabilities.

Discrete The property of a factor or response that only certain levels are allowed.

Distribution The shape data take when plotted on a histogram.

Drift An increase or decrease over time in a factor level or response.

Effect The average difference in a response as a factor varies from its high to its low level. These can be ranked in magnitude to determine the relative importance of terms in a model.

Experiment Design A plan for collecting and analyzing data.

Experimental Error A term encompassing both Systematic Error and Random Response Variation.

External Factor A factor not being studied in an experiment, but influencing one or more experimental responses.

F The ratio of two variances, each divided by its degrees of freedom.

$F_{Critical}$ A value from the F-distribution that is compared to a calculated F statistic in a significance test. This is used to test for statistically significant differences in variances (standard deviations).

F-distribution A distribution used to describe variance ratios.

F-test A test to determine whether a difference between two variance estimates is statistically significant.

Face-Centered-Cubic Design An experiment design for collecting data to fit a full quadratic model. Also called an “Interaction Plus Star Design” or a “Box-Benkhen Design.”

Factor Something over which you have direct control in an experiment.

Factor Transformation A mathematical operation performed on factors to simplify the shape of the response surface.

Factorial Design An experiment design used to study factors and their interactions.

Failure Rate The probability of failing at the next instant in time at time t divided by the probability of surviving until time t. Also called the “Hazard Rate.”

Fractional Factorial Design A factorial design that studies only some of the possible factor interactions, usually just the 2-factor interactions.

Full Cubic Model A polynomial model containing a constant term, a term for each main effect, a term for each two-factor interaction between main effects, a term for the square of each main effect, a term for each 3-factor interaction of the main effects, a term for the interactions of each quadratic main effect with each linear main effect, and a term for the cube of each main effect.

Full Factorial Design A factorial design that studies all possible interactions.

Full Quadratic Model A polynomial model containing a constant term, a term for each main effect, a term for each two-factor interaction between main effects, and a term for the square of each main effect.

G-Optimal Design An experiment design that minimizes the largest variance in the region of interest. While this may the best type of design for DOE work, it is not yet possible to generate these designs to order. The I-Optimal design is the next best choice in most situations.

Gaussian Distribution A distribution of measurement error that is widely applicable to many types of continuous data. This distribution is bell-shaped.

Gosset A program written by Ron Hardin (ATT Bell Labs) to implement NJA Sloane's (ATT Bell Labs) algorithm for gnerating custom, Optimal experiment designs. (See http://www.research.att.com/~njas/gosset/index.html)

Grid Search A method used for finding a Sweet Spot in which the region of interest is divided into a grid, a response is predicted at each grid point, and the grid point or points meeting the goal are listed as potential Sweet Spots.

Hazard Curve The PDF / The Survival Curve.

Hazard Rate The probability of failing at the next instant in time at time t divided by the probability of surviving until time t.

Histogram A plot of data in categories to form a pile of data.

Homogeneous Variance A term used to indicate that the variance (standard deviation) is constant over the region of interest.

Hypercube A multi-dimensional object that represents the region of interest for a four or more factor experiment.

I-Optimal Design An experiment design that minimizes the average variance of prediction over the region of interest. The goal is to make accurate and precise predictions.

In-Control Describes a process which is only subject to common causes of variability.

Interactions Changes in responses due to changes in factor levels that are dependent on other factor levels. The effect of factors changing levels together.

Interaction Design An experiment design for collecting data to fit an interaction model. Also known as "Factorial" or "Fractional Factorial" designs. Interaction Model A polynomial model that includes, at a minimum, a constant term, terms for each main effect, and terms for each 2-factor interaction between main effects. It can also contain higher order interaction terms, such as 3-factor interactions among the main effects.

Interaction Order The number of main effects included in an interaction term.

Interaction Plus Star Design An experiment design for collecting data to fit a full quadratic model. Also called a "Face-Centered Cubic Design" or a "Box-Benkhen Design."

Interval Censored Data Reliability data that do not have precisely known failure times, but are known to have failed between two specific times.

Interval Data Reliability data that do not have precisely known failure times, but are known to have failed between two specific times.

K A constant used to calculate statistical tolerance limits.

Left Censored Data Reliability data that do not have precisely known failure times, but are known to have failed before the test began.

Level A value for a factor.

Life The point in time at which either 50% of units have failed or the average unit will fail. These are usually not the same, so be sure to know which definition is being used.

Life Distribution A histogram or pile of accumulated failures or accumulated failure probabilities.

Lognormal Distribution A distribution of failure times that is widely applicable to many types of reliability data. If log(Failure Time) is plotted the distribution is Normal.

Main Effect A reference to a factor in an experiment as it is represented in a model.

Main Effects Design An experiment design for collecting data to fit a main effects model.

Main Effects Model A model that includes only a constant term and a term for each main effect. This model is used for screening.

Mathematical Model A formula that defines the surface that expresses a theory.

Mean The arithmetic average.

Mean Shift A change in the mean value for a process.

Mean Time to Failure The average time for a unit to fail.

Median The number below which half of a data set fall and above which the other half of this data set fall.

Median Time to Failure The time at which 50%of units are expected to have failed.

Mode The most frequently occurring number in a data set.

Model A theory expressed as a surface.

MTBF Mean Time Before Failure. The Mean time to failure.

MTTF Mean Time to Failure. Same as MTBF.

N Used to indicate the number of replicate measurements.

Np-Chart An attribute control chart used to monitor the number of nonconforming units.

Noise A colloquial term for Random Response Variation.

Normal Distribution A distribution of measurement error that is widely applicable to many types of continuous data. This distribution is bell-shaped.

Normal Probability Plot A plot that displays normally distributed data as a straight line.

Normal Quantile Plot A plot that displays normally distributed data as a straight line.

OFAT One-Factor-At-a-Time. A method for performing experiments in which one factor is varied while all others are held constant.

One-Factor-At-a-Time A method for performing experiments in which one factor is varied while all others are held constant.

Out-of-Control Describes a process which is subject to a special cause or special causes of variability.

p-Chart An attribute control chart used to monitor the proportion of nonconforming units.

p-Level An estimate of the probability of making a type I error.

P_{PK} Similar to C_{PK} , but calculated using the process variability instead of the within sample variability. It measures process performance as opposed to capability.

PDF Probability Distribution Function. In relability, the probability distribution of failing in the next instant at any time t.

Pooled s An estimate of the standard deviation for the region of interest formed by combining separate estimates of the standard deviation by a technique called pooling.

Pooled Standard Deviation An estimate of the standard deviation for the region of interest formed by combining separate estimates of the standard deviation by a technique called pooling.

Pooling A technique which combines standard deviation estimates. Pooling calculates the square root of the degrees-of-freedom-weighted average of the variances.

Power The confidence that two numbers are the same. 1-Power is the probability of making a type II error.

Prediction Interval The interval between a lower and an upper limit in which the next sample measurement is likely to lie with specified probability.

Prediction Limits The lower and upper limits of a prediction interval.

Probability The likelihood that something will occur. For example, the probability that a mean will lie within a 95% confidence interval is 0.95, or 95%.

Process Capability A measure of the ability of a process to meet specifications.

Pure Error An estimate of the standard deviation for the region of interest formed by combining separate estimates of the standard deviation by a technique called pooling.

Quadratic Design An experiment design for collecting data to fit a full quadratic model.

Quadratic Model A polynomial model containing, at a minimum, a constant term, a term for each main effect, and a term for each two-factor interaction between main effects (see interaction model). If it also contains terms for the squares of the main effects it is a “Full Quadratic Model.”

R-Chart A control chart for monitoring ranges in continuous data.

Random Response Variation A description of the naturally occurring phenomenon that introduces random variation into measured data.

Random Run Order A randomly selected order for running experimental trials. The purpose is to protect against being mislead by the effects of external factors.

Range The difference between the highest and lowest values in a set of replicate measurements.

Range Chart A control chart for monitoring ranges in continuous data.

Region of Interest The experimental region over which you would like to make predictions of experimental results.

Reliability The probability that products will satisfy customers without physical or functional failure under stated conditions for a stated period of time.

Reliability Curve A distribution of survival times. See “Survival Curve.”

Reliability Demonstration An experimental demonstration of product reliability including the confidence. For example, 5 failures in 100 samples indicates a minimum reliability of about 89% with 95% confidence.

Replicate An experimental run.

Residual The difference between an observed value for an experimental trial and the corresponding predicted value.

Response Something over which you have no direct control, but which you need to control. You must control responses by adjusting appropriate factors.

Response Surface A model of a response to factor level changes. It is a multi-dimensional surface, having a dimension of 1 + the number of factors.

Response Surface Model A model of a response to factor level changes. It is a multi-dimensional surface, having a dimension of 1 + the number of factors.

Response Transformation A mathematical operation performed on responses to make the standard deviation of the transformed responses constant over the region of interest.

Response Variation A description of the naturally occurring phenomenon that introduces random variation into measured data.

Right Censored Data Reliability data that do not have precisely known failure times, but have not failed before the test ended.

Run To perform an experimental trial. Runs are not unique. One trial can be performed several times, each time counting as a run.

Run Chart A chart plotting measurements in their run order.

Run Order The order in which experimental trials are performed.

s-Chart A control chart monitoring standard deviation for continuous data.

Sample Size The number of replicate measurements performed or to be performed.

Scrambled Run Order A random run order providing better protection against shifts, drifts, and cycles than other random run orders.

Screening The act of reducing the number of factors in an experiment to a more manageable size.

Shift An immediate change in a response value.

Significance Importance of an observed difference.

Significance Test A test to determine if an observed difference is important in terms of probability. In other words, if the probability of a difference being real is sufficiently high, this test will indicate that the difference is important.

Sigma The symbol for the true standard deviation. We can never know the true standard deviation because it is obscured by response variation, so it is a theoretical idea.

Significant Important.

Six Sigma A program for improving decisions using data and statistical analysis.

SPC Statistical Process Control, a system for monitoring process performance.

Special Cause A cause of variation in a process that is not a part of normal operation.

Special Cubic Model A full cubic model minus the terms for the cube of each main effect. This is often used to study mixtures and is presented in an equivalent form that has no constant term. Please see Math Options texts for more details.

Standard Deviation Half the height of a normal distribution at half its width.

Standard Deviation Chart A control chart monitoring standard deviation for continuous data.

Star Points Experimental trials added to an Interaction Design or a Factorial Design to allow a fit to a full quadratic model. They are located at the centers of edges in square regions of interest and in the centers of faces in cubical and hypercubical regions of interest.

Statistical Control Describes a process which is only subject to common causes of variability.

Statistical Process Control A system for monitoring process performance.

Statistically Significant Refers to the probability that a difference is real is high.

Statistical Tolerance Interval The interval in which a specified proportion of all future measurements should lie with a specified probability.

Statistical Tolerance Limits The lower and upper limits of a tolerance interval.

Survival Curve A distribution of survivors to a given point in time. It is 1 – the Life Distribution.

Sweet Spot A combination of factor levels that satisfies all response goals.

Student's t Value A value from a t-distribution.

Synergism An interaction between factors producing a response better than anticipated when considering the factors separately.

Systematic Error An error which can, if identified, be eliminated, at least in theory.

t A value from a t-distribution.

$\mathbf{t_{critical}}$ A value from a t-distribution that is compared to a calculated t-value in a significance test.

t-Test A significance test that compares means.

$\mathbf{T_{50}}$ Median time to failure.

Tolerance Interval The interval in which a specified proportion of all future measurements should lie with a specified probability.

Tolerance Limits The lower and upper limits of a tolerance interval.

Transformation A mathematical operation performed on responses to make the standard deviation of the transformed responses constant over the region of interest, or on factors to simplify the shape of the response surface.

Twisted Plane Interactions cause a plane to twist. An interaction between two factors manifests itself in a response surface as a twisted plane.

Trial A set of factors and levels for an experiment.

Type I Error Concluding that a difference is real when it is not.

Type II Error Concluding that a difference is not real when it is real.

u-Chart An attribute control chart that monitors the proportion of non-conformities.

Uncertainty The doubt about a conclusion due to Random Response Variation.

Uniform Shell Design An experiment design for a spherical region of interest that is more efficient than the Central Composite Design but less efficient than I-Optimal Designs can be.

Uniform Standard Deviation A term used to indicate that the standard deviation is constant over the region of interest.

Variable Data Continuous data.

Variables Control Chart Any control chart monitoring continuous data.

Variance The square of the standard deviation.

Weibull Distribution A distribution of failure times that is widely applicable to many types of reliability data.

Width of a Pile of Data The width of a histogram. For a normal distribution this is generally considered to be 6 times the standard deviation.

X-Bar Chart A control chart monitoring averages for continuous data.