Statistical Methods for Defense and Aerospace Applications using Systat

Introduction

Aerospace and defense engineers must develop and deploy sophisticated, mission-critical components for aircraft, spacecraft, missile, and propulsion systems while integrating their work with teams involved with other parts of the design. They also need to handle and comprehend the huge amounts of test data and other data generated during their work. Major aerospace and defense research institutions, and defense agencies worldwide use statistical software products like **Systat** to analyze data, model and simulate systems or components.

Design of Experiments (DOE)

Poor quality in any arena can be traced to variation in parts, materials, people, and processes. The larger the variation, the poorer the quality. It has been observed that all work can be broken down into processes. All processes, whether manufacturing or administrative in nature, have inherent variability, which affect their quality.

DOE has been a method suitable for application to quality improvement since the work of Sir Ronald Fisher in the 20s. The spread of the method in different fields including the engineering domain is well known. Many individual efforts have led to more & more use and a deeper understanding of DOE. In this regard, the contributions of Taguchi are important and so are company wide quality improvement initiatives such as Six Sigma programs.

Many experiments in defense and aerospace domain are done to determine how a system responds to a change in some factor(s). This is the sort of experiment that would be done to optimize the performance of the system, for example, or to characterize the system as part of a validation effort. Careful planning at the outset of these experiments can save a great deal of time and effort.

So what is DOE? DOE is a planned approach for determining cause and effect relationships that can be applied to any process with measurable inputs and outputs. DOE provides a statistical means for analyzing how numerous variables interact. So how can **Systat** help in this regard?

Systat offers three methods for generating experimental designs: Classic DOE, the DOE Wizard, and the DESIGN command.

Box-Behnken Design: 15 Runs;
3 Factors, Each With 3 Levels

Run	Factor 1	2	3
1	-	-	0
2	+	-	0
3	-	+	0
4	+	+	0
5	-	0	-
6	+	0	-
7	-	0	+
8	+	0	+
9	0	-	-
10	0	+	-
11	0	-	+
12	0	+	+
13	0	0	0
14	0	0	0
15	0	0	0

Classic DOE provides a standard dialog interface for generating the most popular complete (full) and incomplete (fractional) factorial designs. Complete factorial designs can have two or three levels of each factor, with two-level designs limited to two to seven factors, and three-level designs limited to two to five factors. Incomplete designs include: Latin square designs with 3 to 12 levels per factor; selected two-level designs with 3 to 11 factors and from 4 to

Latin-Square Design:
4 Factors, Each With 4 Levels

Factor 1	Factor 2: 1	2	3	4
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	C

128 runs; 13 of the most popular Taguchi designs; all of the Plackett and Burman two-level designs with 4 to 100 runs; the 6 three-, five-, and seven-level designs described by Plackett and Burman; and the set of 10 three-level designs described by Box and Behnken in both their blocked and unblocked versions. In addition, the Lattice, Centroid, Axial, and Screening mixture designs can be generated.

The DOE Wizard provides an alternative interface consisting of a series of questions defining the structure of the design. The wizard offers more designs than Classic DOE, including response surface and optimal designs. Optimization methods include the Fedorov, k-exchange, and coordinate exchange algorithms with three optimally criteria available. The coordinate exchange algorithms accommodate both continuous and categorical variables. The search algorithms for fractional

factorial designs allow any number of levels for any factor and search for orthogonal, incomplete blocks if requested.

The DESIGN command generates all designs found in Classic DOE using **Systat's** command language.

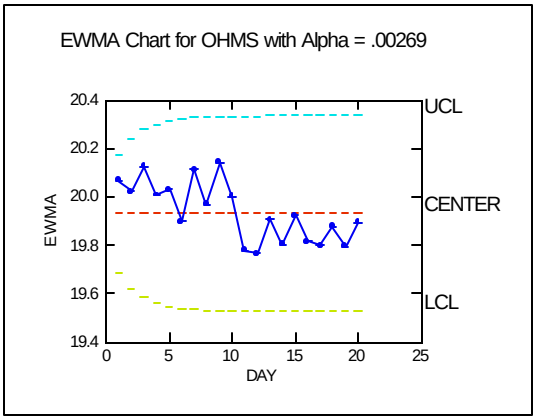
Technical Data Analysis

Aerospace / defense industry face continuing pressure to produce more, higher reliability and lower cost devices every year. Since the industry is heavily data oriented, statistical softwares like **Systat** has to convert that data into information that leads to action.

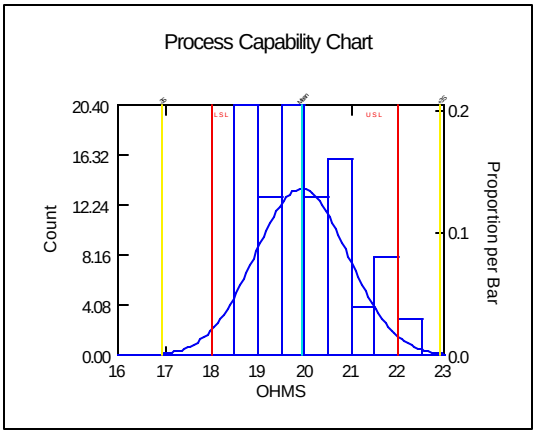
Quality Control for Defect Analysis

Modern quality control places an emphasis on designing quality into products, in addition to the more traditional function of monitoring a process to ensure that quality is maintained.

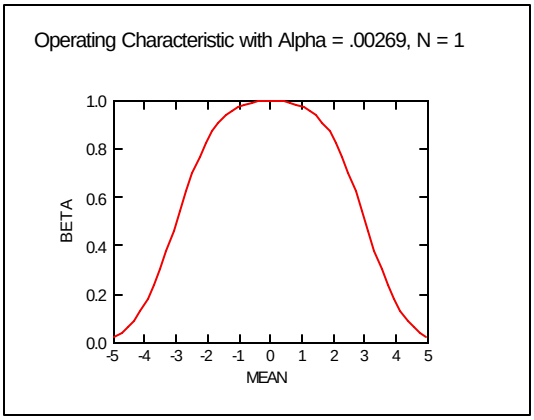
Systat software provides 11 types of Shewhart charts (X-bar, variance, s, R, X-bar and s, X-bar and R, X, np, p, c, or u), plus Pareto, box and whisker, moving average, exponentially weighted moving average, regression, cumulative sum, TSQ (Hotelling's T-squared), and process control analysis charts.



Process control analysis in **Systat** produces the capability indices Cp and Cpk for a variable that you name, as well as showing you a histogram of the data, overlaid with a normal curve that conforms to the mean and variance of the input data. Specification limits that you provide are shown on this histogram, as well as the empirical mean and 3-sigma limits of the data.



Systat software plots an operating characteristic (OC) curve for any of eight statistical distributions, showing the probability of a Type II error (beta) as a function of a range



of possible expected values of the sampling distribution. The distribution used depends on the chart type.

Conclusions

The description above just gave a bird's eye view of **Systat's** capabilities. But **Systat** provides a powerful statistical and graphical analysis system in a graphical environment using descriptive menus and simple dialog boxes. **Systat's** command language provides functionality not available in the dialog box interface in addition to complete coverage of menu-based functionality. Robust algorithms from leading statisticians give meaningful results even with extreme data. Create missing value estimates using regression-based point estimation or an EM algorithm. Obtain complete distributions and standard errors using **Systat's** bootstrapping capability implemented globally across 21 statistical procedures even when normality assumptions are violated and no model is available. Matrix procedure allows you to use matrix algebra to specify statistical analyses and perform data management tasks.

Systat offers more scientific and technical graphing options than any other desktop statistics package. Compare subgroups, overlay charts, and transform coordinates, change colors, symbols and more to create insightful presentations. Speed up your analysis by rotating your 3-D graphs to visually determine the perfect power or log transformation to normalize your data using the Dynamic Explorer to speed up your analysis.

Create compelling reports by combining formatted statistical output with publication-quality graphs in **Systat's** rich text output window.