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ABOUT STAT-EASE SOFTWARE, TRAINING, AND CONSULTING FOR DOE
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Workshop Schedule

DOE Simplified
October 5, 2004: MN Quality Conf., Mpls, MN

An overview of Design of Experiments (DOE) from A to Z, based on the popular book. (Register through MN ASQ.)

Statistics for Technical Professionals
October 6–7, 2004: Minneapolis, MN
February 16–17, 2005: Minneapolis, MN

Revitalize the statistical skills you need to stay competitive. $995* ($795 each, 3 or more)

Experiment Design Made Easy
November 2–4, 2004: Minneapolis, MN
December 7–9, 2004: Anaheim, CA
January 25–27, 2005: San Jose, CA
March 1–3, 2005: Minneapolis, MN
March 29–31, 2005: Philadelphia, PA

Study the practical aspects of DOE. Learn about simple, but powerful, two-level factorial designs. $1495* ($1195 each, 3 or more)

Response Surface Methods for Process Optimization
October 12–14, 2004: Minneapolis, MN
March 15–17, 2005: Minneapolis, MN

Maximize profitability by discovering optimal process settings. $1495* ($1195 each, 3 or more)

Mixture Design for Optimal Formulations
November 9–11, 2004: Minneapolis, MN
February 1–3, 2005: Minneapolis, MN

Find the ideal recipes for your mixtures with high-powered statistical tools. $1495* ($1195 each, 3 or more)

Robust Design: DOE Tools for Reducing Variability
April 12–14, 2005: Minneapolis, MN

Use DOE to create products and processes robust to varying conditions. A must for Six Sigma. *Factorial and RSM proficiency are required.* $1495* ($1195 each, 3 or more)

PreDOE: Basic Statistics for Experimenters
Six-hour web-based training. This course or the equivalent is a prerequisite for all workshops—**www.statease.net**. $95

Attendance is limited to 20. Contact Sherry at **800.801.7191 x18** or **sherry@statease.com**.

**Includes a $95 student materials charge which is subject to state and local taxes.*

Stat-Ease
statistics made easy

Playing with Paper Helicopters

Some years ago, I attended a seminar at the University of Wisconsin put on by George Box, a pioneer in the development of DOE. For a show-and-tell session, a graduate student carried a ladder into class and dropped a paper helicopter.[1] It whirly-gigged at an amazingly slow rate from ceiling to floor—providing an impressive demonstration of the power of DOE. Figure 1 shows results from an early phase of the experimental program when the graduate student applied Box's method of steepest ascent.[2] The symbol that looks like a sideways "Y" represents the time in seconds for the helicopters displayed on the right axis. Notice that it peaks at Step 3. The paper dimensions are provided on the left axis with a legend for the corresponding elements of the helicopter.

Many years ago, inspired by Box and his student, I prevailed upon my partner Pat Whitcomb to include experimentation on helicopters in a few Stat-Ease workshops on DOE. It proved to be very fun and educational, but to give

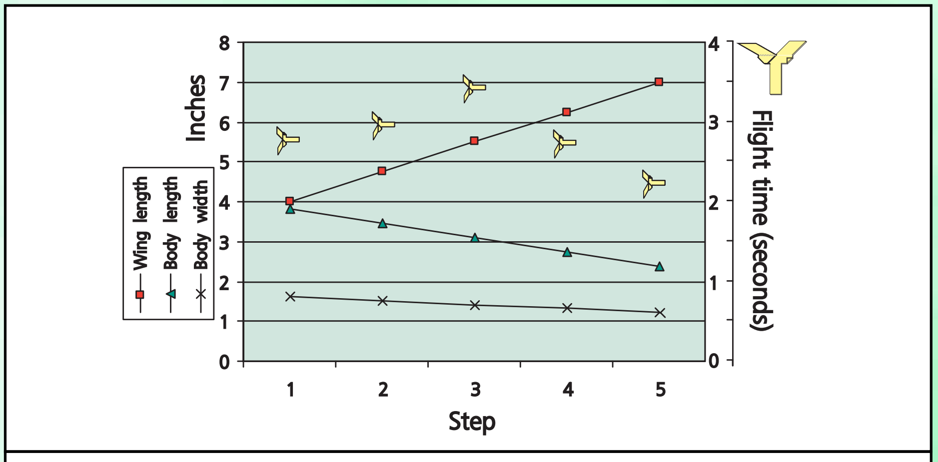

Figure 1: Step-by-step helicopter plot

—Continued on page 2.

—*Continued from page 1.*

students enough time to do it properly, we had to forego too much valuable content. Instead, we now make extensive use of simulations for generating data sets that incorporate real-life variation.

This Spring, I enjoyed the opportunity to dust off the paper helicopter exercise[3] for DOE classes at Ohio State University (OSU) and the South Dakota School of Mines and Technology (SDSMT), where Pat also taught on behalf of Stat-Ease. The picture on Page 1 shows two graduate students at SDSMT, from left to right: Bhavani Puli (MS, Chemical Engineering) and Haribabu Papisetty (MS, ChE), watching a flight of their team's best helicopter based on results from a two-level factorial design.

You may observe that a plate lies on the white square on the floor. We asked our students to imagine this to be a circular landing pad placed on the top of a tall building. Each team dropped their best helicopter three times. The primary goal was to achieve the longest flight time on average, but we also kept track of accurate landings onto the plate. Helicopters that fell off the "building" were considered to be a disaster.

We had previously taught DOE at SDSMT, but this was the first opportunity to integrate a student project into the curriculum—essentially the Experiment Design Made Easy (EDME) workshop divided into three sessions, several weeks apart. The host for the presentation by Stat-Ease, Professor Dave Dixon of SDSMT, said of the added exercise, "the helicopter project went well and I especially appreciated your direct and timely feedback during the student presentations. That kind of feedback really makes for great learning opportunities." My experience with the helicopter exercise differed somewhat at OSU, in part because it involved executives training for Master Black Belt (MBB) status in Six Sigma quality programs at their respective companies. Not surprisingly, these students took a much more business-like approach to organizing their teams, wasting no time in developing a plan of action and then executing the experiment—all within only a few hours of time spent in-class. However, after losing track of one of my teams I searched all over OSU's Fisher College of Business, the sponsor of my Six Sigma DOE session. I discovered them dropping paper helicopters down a little-used stairwell at the back of the building!

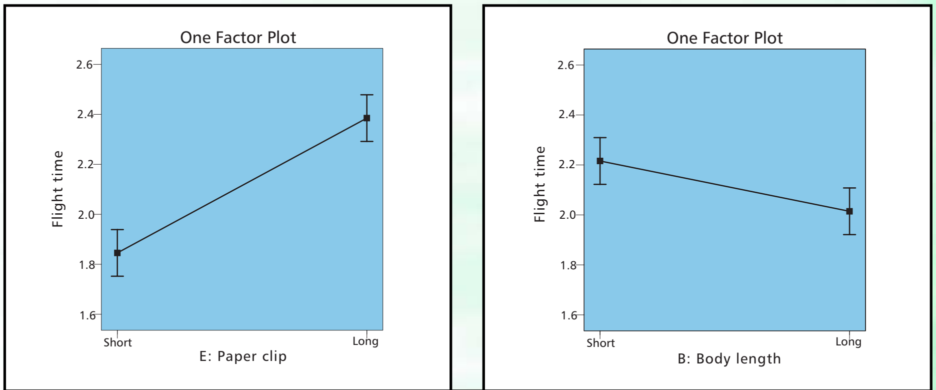

Figure 2: The main effects of wing and body length

Mean flight time results from one of the OSU experiments are shown in Figure 2 for the significant effects: wing length (the longer the better) and body length (the shorter the better—marginally).

These experimenters dropped each helicopter three times and measured accuracy in terms of how many hit a one-foot diameter circle when dropped from a height of eight feet. As evidenced by the accuracy effect plot (Figure 3), adding a paper clip significantly improved on-target performance.

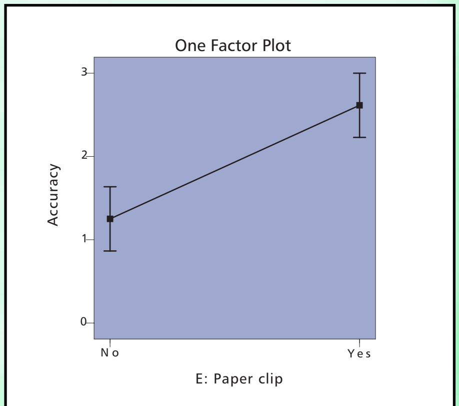

Figure 3: Accuracy effect plot

Other factors were tested, but these three were all that mattered statistically. This particular outcome is what Six Sigma programs strive for—improving the level of performance (via longer wing span and shorter body) while simultaneously reducing process variability (by adding a paper clip). With results like these, which were fairly typical, the helicopter exercise proved to be valuable practice on DOE for the MBB's at OSU and graduate students at SDSMT.

—*mark@statease.com*

[1]Box, George. "George's Column: Teaching Engineers Experimental Design with a Paper Helicopter," Quality Engineering, 4 (3), pages 453–459, 1992.

[2]Box, George, and Patrick Liu. "Product Design with Response Surface Methods." Center for Quality and Productivity Improvement, Report No. 150 (May 1998). University of Wisconsin, Madison.

[3]Instructions and templates available upon request.

Power—How Many Runs Do I Need?

Have you ever run a designed experiment and NOT found any statistically significant effects? Most people have encountered this at some point during their experimentation. Generally, significant effects are not found because the power of the design to detect effects is not sufficient. The "power" of a design is the probability that effects of a certain size will be uncovered (found significant) during data analysis.

Design-Expert® software provides power calculations in the Design Evaluation section of the program. Power is based on a signal to noise ratio, and then calculated in relation to both the number of effects to estimate and how many runs are available. Let's illustrate this definition by using information from the experiment I completed last year on plant growth (Stat-Teaser, March 2003). I wanted to see how various factors such as pot size, soil type, location, etc. effected the change in width, height, and circumference of the plants.

Signal—this is the minimum change in the response that you feel is practically important. Ask yourself, what change in the response would make my customer interested? I decided that a two-inch change in height from plant to plant was important to me, so this is the signal (effect) I wanted to detect.

Noise—this is the standard deviation of the process. This information could come from your quality or product database. If this information hasn't been collected before, you may need to collect measurements on the current process and calculate the standard deviation for the response. If you are developing a brand-new product and you don't have history, you may have to SWAG it (take a scientific, wild-"asterisked" guess!). I collected information from current plants and determined that the standard deviation in plant height was approximately one-inch.

Power at 5% alpha level for effect of:

1/2 Std. Dev.	14.8 %
1 Std. Dev.	44.0 %
2 Std. Dev.	94.9 %

Figure 1: Power information

Signal to Noise (S/N) ratio—put these two pieces of information together to determine the ratio. For my plant DOE, the ratio is 2/1. This means that the effect of interest is two times the standard deviation. This is important because in Design-Expert power is presented in these terms and you have to choose the power information that is closest to your situation.

For my five-factor design, I selected a 16-run half-fraction factorial. Before running the design, it is important to know if it is capable of detecting the effects that I hope to see. I built the design and then went to Design Evaluation. Since power is calculated based on the number of effects that will be active, I chose to evaluate the design based on a Main Effects model. Clicking on the Results button provides the power information shown in Figure 1. Since my calculated Signal to Noise ratio is 2, I look at the 2 Std. Dev. row and can see that this design has a 94.9% probability of finding an effect that is 2 times larger than the noise. Statisticians recommend that power be at least 80%, so this design should find the effects that I had decided would be important.

What's in this for me?

The key question for experimenters is: How many runs do I need in order to detect my effects? First, determine your signal to noise ratio. Then, look at Figure 2. It shows that an 8-run design is capable of detecting effects that are 3–4 times larger than the noise. These are quite large effects! Smaller effects are less likely to be found in only 8 runs. Designs with 16 runs are generally capable of finding effects that are approximately 1.5 to 2 times the standard deviation of the response. As the number of runs increases, the ability to find smaller effects increases.

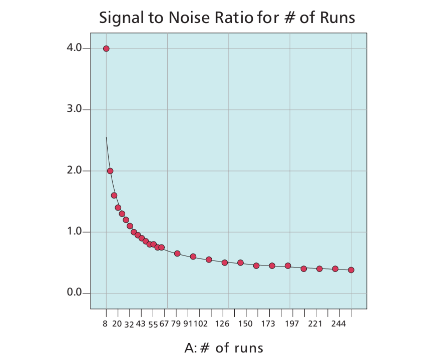

Figure 2: S/N ratio vs. # of runs

Choosing a design that is too small will lead to wasted effort. Make the most of your resources and think about power when determining how many runs to complete.

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Check Out Our Web Resources!

09/04

Have you checked out the resources on our web site lately? You'll find many papers written by Stat-Ease consultants on various DOE-related topics, plus case studies written by other Design-Expert users. You can also access our archive of past Stat-Teaser and DOE FAQ Alert newsletters. Try using the search engine if you are looking for a specific topic. A sampling of articles is listed below:

For more information on Power, try the following articles:

Sizing Fixed Effects for Computing Power in Experimental Designs: http://www.statease.com/pubs/power.pdf
Interpreting Power in Mixture Designs: http://www.statease.com/pubs/powerinmixsimp.pdf

For information on reducing variation try:

Augmented Ruggedness Testing to Prevent Failures: http://www.statease.com/pubs/ruggednesstest.pdf
The Six Sigma Method and Design of Experiments: http://www.statease.com/pubs/sixsigma&DOE.pdf

For a list of easy-to-do experiments that you can do at home or in a classroom environment, please read:

DOE-it-Yourself: http://www.statease.com/pubs/doe-self.pdf
Tabletop Hockey Meets Goals for Teaching Experimental Design: http://www.statease.com/pubs/hockey.pdf

"I got your book, DOE Simplified, *and used your tabletop hockey game for our BB training class. The students love it and it's a great teaching tool. Thanks!"*—Katrina M. Labude, Master Black Belt, Six Sigma, ConocoPhillips

Other articles of interest:

How Experimental Design Optimizes Assay Optimization: http://www.statease.com/pubs/optimizeassays.pdf
Screening Process Factors in the Presence of Interactions: http://www.statease.com/pubs/aqc2004.pdf
How to Use Graphs to Diagnose and Deal with Bad Data: http://www.statease.com/pubs/baddata.pdf
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