Stat Teaser

ABOUT STAT-EASE® SOFTWARE, TRAINING, AND CONSULTING FOR DOE • SEPTEMBER 1999
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Workshop Schedule

• Experiment Design Made Easy

October 26-29: Detroit, MI
November 9-12: Philadelphia, PA
December 7-10: Anaheim, CA

Covers the practical aspects of Design of Experiments (DOE). Learn about simple, but powerful, two-level factorial designs.

• Response Surface Methods for Process Optimization

October 5-7: Minneapolis, MN
February 8-10, 2000: Dallas, TX

Find the optimum settings for your process. Generate 3D maps to identify the peak area and overlay plots to find your sweet spot.

• Mixture Design for Optimal Formulations

October 19-21: Minneapolis, MN
January 25-27, 2000: Atlanta, GA

Standard factorial designs don't work well for formulations. Learn all the skills you need for mixture designs in this course.

• Robust Design: DOE Tools for Reducing Variation

December 7-9: Rochester, NY **(New Site)**

Use DOE to create products and processes that are robust to varying conditions. Factorial & RSM proficiency is required.

• Real-Life DOE (New Class)

September 28-30: Minneapolis, MN

No textbook data - analyze real data sets and learn how to deal with common pitfalls and analysis problems! Working knowledge of factorial designs is required.

Attendance limited to 20. Reserve your place by calling Sherry, ext. 18, at **(800) 801-7191**

X-Factor Files Divulge Minnesota Mystery: Alien Plot?

Mark's Experiment
by Mark J. Anderson

I've always believed that a graph is worth 1000 numbers, so several years ago I purchased a book called *Visualizing Data* by William S. Cleveland (Hobart Press, 1993). Cleveland introduces his book with a rehash of a landmark field trial on barley in my home state of Minnesota. Agronomists grew 10 varieties of the crop at 6 sites in the years of 1931 and 1932. The study was re-analyzed by R. A. Fisher, the father of design of experiments (DOE), and later by Cuthbert Daniel, who made important contributions to the analysis of 2-level factorials. Neither of these authors discovered an anomaly in the data: At all but one site the yields in year 1 were significantly higher. Cleveland uses dot plots to reveal this oddity. He claims that the original authors accidently reversed the numbers in their report (Immer, et al, *Journal of Agronomy*, 26, 403-419, 1934). After watching the X-Files show and movie, I wonder if something more sinister could be the cause. My partner Tryg suggested that this is literally a case of an alien "plot". But before developing our theories further, I decided to apply the tool of general factorial analysis, now available in beta version 6 of Design-Expert® software (DX6) from Stat-Ease, Inc.

I found data for five of the varieties in Daniel's book (*Applications of Statistics to Industrial Experimentation*, Wiley, 1976, p. 160). Table 1 shows the data (trans-

		Varieties				
Location	Year	M	S	V	T	P
1	1	81	105	120	110	98
	2	81	82	80	87	84
2	1	147	145	151	192	146
	2	100	116	112	148	108
3	1	82	77	78	131	90
	2	103	105	117	140	130
4	1	120	121	124	141	125
	2	99	62	96	126	76
5	1	99	89	69	89	104
	2	66	50	97	62	80
6	1	87	77	79	102	96
	2	68	67	67	92	94

Table 1: Barley Yields (Bushels per Acre)

continued on page 3 -

DOE Conference a Success!!

The first Stat-Ease DOE conference was a tremendous success. Attendees polished their DOE skills by learning about analysis techniques for everything from general factorial designs, to mixture designs, to propagation of error. Stat-Ease unveiled the long awaited Design-Expert software, beta version 6 (DX6). Although it is still in the final stages of beta testing, DX6's new features were demonstrated throughout the 2-day conference.

Pat Whitcomb presented a talk on the analysis of general factorials, a powerful new design option in DX6. The analysis is a bit trickier than two-level factorials because, instead of using the half-normal plot to choose effects, the experimenter must look at term probabilities or simply choose the higher order interactions to estimate error.

Pat also illustrated the use of crossed designs. These new designs allow an experimenter to add process factors such as time or temperature to a mixture design. A D-optimal selection of design points prevents these designs from becoming unbearably large. The analysis and interpretation is a bit more complex due to the increased number of terms, but DX6 handles it well!

Patrick Whitcomb (President of Stat-Ease) standing with Dr. Douglas Montgomery at the Keynote Dinner.

Dr. Douglas Montgomery gave the keynote address Thursday evening. He described the development of DOE starting with its agricultural beginnings with Sir Ronald Fisher in the 1920's. After presenting this background information, Dr. Montgomery talked about interesting new developments in the DOE field, specifically new tools for non-normal data. Non-normal data is a common problem that traditionally has been handled through the use of transformations. (Editor's note: DX6 offers a new diagnostic tool called a Box Cox plot to help choose power transformations.)

Dr. Montgomery is a captivating speaker. It was exciting to hear Doug's suggestions for improved analyses!

Note: A limited number of copies of the 1999 Stat-Ease DOE Conference Proceedings are available on a first-come, first-served basis for $50. The proceedings contain complete course notes for all seven talks. Included in the notes are detailed instructions for working out each of the case studies presented. Call soon for more information or to place an order. Supplies limited.

Sneak Preview of Design-Expert v.6!!

The development and testing of Design-Expert software, version 6 (DX6) is well underway. Version 6 is full of new designs and new tools to explore. Here is a partial list of what you can expect!

New Designs
- General Factorials - multi-level designs for categorical factors
- D-optimal fractional factorials for multi-level designs
- Crossed mixture and process factor designs
- Taguchi orthogonal arrays (19 designs from L4 to L64)
- Fractional factorials for 256 runs

New Graphs
- Box Cox plot for choosing power transformations
- Predicted vs Actual diagnostics plot
- Propagation of Error (POE) graph for transformed responses and mixtures
- Interaction and One Factor graphs for RSM designs
- Interaction graphs in the original scale for a transformed response

New Analysis Features
- Confidence intervals on coefficients
- Annotated ANOVA view
- Toggle between aliased interactions
- Ability to add user-defined polynomial terms, such as quartic
- Power calculations add to design evaluation

Expanded Flexibility
- Add categorical factors to response surface designs
- Ignore a row of data (rather than deleting it)
- Add new factors to existing designs
- Toggle factors from categorical to numeric and back
- Change model from RSM to factorial and back
- Choose a significance threshhold of 99%, 95% (default) or 90%

Numerical Optimization
- Include categorical factors!
- Set factors to a specific level

New Help System
- Expanded context-sensitive help
- On-line help manual - updated and improved
- Interpretation of ANOVA results

Design Evaluation
- Power calculations to determine the ability of a design to detect effects

Watch for a special mailing with information regarding the release of DX6. Upgrades will be available at low cost to current users of Design-Expert software. Paid-In-Advance orders will be accepted. Call for more information if you are interested.

New Tools for Experienced Experimenters!

Real-Life DOE (New Class)
Sept. 28-30, '99, Minneapolis, MN

The examples you see in the classroom and textbooks always have a storybook ending. Unfortunately, in real life people don't live happily ever after. You get back to work, do the DOE's recommended, and then must deal with "messy" data. Many of you end up dumping those data sets on us. Now we've designed a class around these real-life cases to teach you the tricks to analyzing them.

We'll start out doing a quick review of factorial and fractional factorial designs, including a graphical exploration of aliased interactions. From there we'll explore the process of wine-making, initially using a screening design, then following up by studying only the significant factors.

Do you have an effects plot that looks like Figure 1? Where are the significant effects? Now what do you do? Do you have to throw away the money and time you've already invested, or is there some way of clarifying this picture? We'll illustrate the effect that outliers, botched runs, and missing data can have on your analysis, and teach you how to get the most information out of a difficult design.

Fruit pies provide food for thought when analyzing irregularities in residual plots. A case study exploring loose collets on lathes reinforces the concept. A five-axis CNC machine forces you to explore a large number of factors in a fractional factorial with blocks. Aliases cause difficulties but they can be sorted out!

You have requested the ability to explore factors with multiple levels. Design-Expert 6 provides a general factorial design builder that gives you the flexibility to set up any type of factorial design you need. Learn how to analyze these designs (you can't use the effects plot with general factorials!) Also, learn how to use D-optimality to reduce the number of runs needed for a general factorial design.

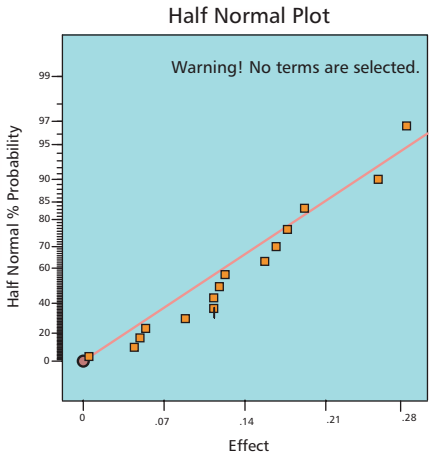


Figure 1: Are there any significant effects here? Come to class and find out!

The 3-day Real-Life DOE workshop is computer intensive. We guarantee that it will increase your ability to analyze factorial DOE's. The only prerequisite to this workshop is a working knowledge of factorial designs. We're presenting the workshop in Minneapolis on September 28-30, 1999. It is also available as an in-house course. Call us for a quote.

Robust Design: DOE Tools for Reducing Variation (New Site)
Dec. 7-9, '99, Rochester, NY

Do you want to create a process that has minimal variation? Or deliver a product to your customers that is robust to outside influences? DOE is the tool for you! We'll show you how to use propagation of error (also known as tolerance analysis) to minimize variance transmitted from control factors.

The workshop allows you to try out leading edge techniques such as:

- Factorial designs for ruggedness testing
- Parameter (Taguchi) designs for finding control factors that will minimize the impact of noise variables
- Dual response methods to investigate variation as well as the mean level of performance
- Propagation of error for transformed responses as well as factorial, response surface, and mixture designs.

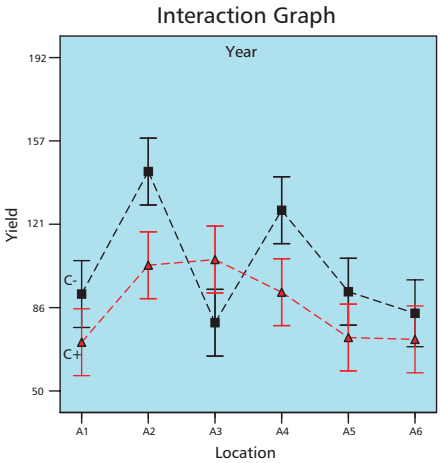
You'll use the latest version of Design-Expert software in class to evaluate case studies and perform simulations.

This is an advanced workshop in designed experiments. You need not be a statistician, but participants are expected to have a working knowledge of both factorial and response surface designs. For those of you involved in six sigma manufacturing, this is equivalent to a green belt.

- continued from page 1

formed back to original units of measure).

I entered this into DX6 beta and did an analysis of variance (ANOVA). Sure enough, by using the 3-way interaction estimates as error, the output revealed a significant interaction for sites by year. By not plotting the data, the original authors missed the anomaly shown at site A3 (Morris, Minnesota). You can see the reversal in Figure 1.



My analysis with DX6 supports Cleveland's contention. You can decide for yourself if the cause is alien in nature, or just human error.

Mark Anderson
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Figure 1 : Interaction Graph for Site vs. Year (from DX6). Year 1 is the black line and Year 2 is the red line.

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☐ **Case Study 7:** **"Statistical Design"** (by Terrance A. Rooney) Reprinted from TODAY'S CHEMIST AT WORK, 1998, Vol. 7, No. 11. A chemist, turned computer consultant, investigates the power of DOE with the latest software tools available.

☐ **Case Study 19:** **"Nonexperimenter Tries DOE Software"** (by Rich Burnham) Reprinted from PAINT & COATINGS INDUSTRY, November 1998. A newcomer to DOE reviews Design-Expert v5 software from Stat-Ease, Inc.

☐ **Case Study 23:** **"Solving Core Shear with Design of Experiments"** (by Stat-Ease, Inc.) Reprinted from JOB SHOP TECHNOLOGY, March 1999. A foundry uses DOE methods to find the ideal combination of casting components to halt hairline fractures in bolt-hole cores.

☐ **Case Study 24:** **"Improve PCB Gold-Plating Yields Using DOE"** (by Mark J. Anderson) Reprinted from ASIAN SOURCES ELECTRONICS ENGINEER, November 1998. Factorial designs identify significant factors for a circuit board manufacturer, improving yield and significantly reducing rework.

☐ **Case Study 26:** **"Design of Experiments for Process Validation"** (by M. J. Anderson & P. J. Anderson) Reprinted from MEDICAL DEVICE & DIAGNOSTIC INDUSTRY, January 1999. Designed experiments are used to perform validation testing on a paraffin therapy bath. When validation fails, a foldover technique reveals the problem.

☐ **Case Study 32:** **"How to Select Design of Experiments Software"** (by Rich Burnham) Reprinted from QUALITY DIGEST, November 1998. Discussion of the features to look for in a statistical software package. An excellent guide for anyone starting out in the DOE world.

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