Preface

In today's competitive business environment, many companies are seeking ways to increase their efficiency in tasks such as manufacturing process troubleshooting, new process development, and new product development. New process and product development include prototype testing, development of new component and system design configurations, raw material selection, and determination of appropriate component tolerances. Because deterministic relationships for solving these problems are often not known, industrial research programs or technical investigations usually involve trial and error.

Every technical investigation involving experimentation embodies a strategy (either consciously or unconsciously) for deciding what experiments to perform, when to quit, and how to interpret the data. There are as many different strategies as there are investigators. Some are good and some not so good. This text presents several statistically derived strategies which give greater efficiency than the more intuitive approaches. That is, the use of statistical experimentation strategies will generally get the investigator to his goal in the shortest time (i.e., running the fewest experiments), give the greatest degree of reliability to his conclusions, and keep the risk of overlooking something of practical importance to a minimum.

These statistical experimentation strategies were first developed for use in agricultural research, and they continue to be used successfully on a wide scale in that type of research. The methods have also been commonly used in chemical manufacturing and in electronic circuit design in Japan. However, for the most part these techniques have not been widely used in industry. The reasons for this lack of use are partly historical and cultural and partly due to misconceptions. Historically, statistical experimentation strategies are a relatively recent tool, having been developed for industrial use only since about 1940. Many business managers are not aware of the methods since they are not as glamorous or attention getting as factory automation, artificial intelligence, or robotics. Also, most engineers have had little or no training in the use of these methods. Culturally, industrial managers are often rewarded for working around problems or obtaining quick fixes. This does not favor use of statistical experimental strategies which seek understanding and permanent solutions to recurring problems. Finally, statistical experimentation strategies are often thought to be complicated, lengthy, and costly, and, therefore, reserved for "special" problems where they are often misused due to lack of experience. However, as this text shows, statistical experimentation strategies are actually simple to use, and are neither costly nor lengthy. Herein lies a straightforward presentation of the information necessary for engineers to begin applying these techniques. Companies that utilize these strategies as standard operating procedures can expect large cost reductions in manufacturing, improved product quality, and reduced lead time for the introduction of new products and/or manufacturing methods.

This text is a technical manual which presents methods an engineer or scientist can use to plan an experimental program in two basic situations: (1) screening out which variables are important from a multitude of possible candidates, and (2) optimizing with respect to the relatively few important variables to find the combination of variable settings that gives the best response (or the best compromise among several responses). Enough basic statistics will be presented so that the novice can perform the analysis and interpretation of experimental data, as well as appreciate the reasoning behind the statistical methods. The book illustrates how data analysis can be accomplished with common spreadsheet programs such as Excel© or the open source programs Libre Office Calc or Open Office Calc. Some examples in the book show the use of the statistical software such as the commercial program Minitab© or the open source program R, but the common spreadsheet is capable of handling the majority of the types of analysis presented.

In the past, the material in Chapters 1, 3, 4, 7, and 9 (with light emphasis on the least squares method in Chapter 8) has been covered in a three-day workshop. A prerequisite for course participants has been a familiarity with basic statistical concepts and methods covered in Chapter 2. Chapter 2 is included in the text for review purposes and for setting the stage for the statistical analysis tools used in the following chapters. Course participants should study, read, and review Chapter 2 prior to attending a workshop. Normal workshops have consisted of morning and afternoon lectures followed by in-class simulation problems wherein participants work in groups and report their results. Other workshop formats have also been used. With one or two half-day sessions per week, a wider selection of topics has been successfully covered in five- to ten-week periods. The most successful workshops have a follow-up meeting several weeks after the conclusion of the course. In this follow-up meeting, teams of course participants present results of experimental studies conducted on the job utilizing techniques they learned in the course.

In an academic setting, the whole book is generally covered in a one-semester course. If time is short, Chapter 12 can be omitted without loss of comprehension of the rest of the material. No prerequisites in statistics or mathematics are required, although some background in matrix algebra is helpful (but not essential) in Chapter 8. The text material is supplemented by requiring students to run experiments on their own using the various designs discussed in the course (e.g., screening, factorial, etc.) and then to analyze the results and report their conclusion. A course such as this goes a long way in reducing the serious lack of training in statistics and experimental design that most engineering graduates have.

Author Bios

John Lawson—is a professor in the Department of Statistics at Brigham Young University (BYU) where he has been for the last 30 years. He obtained his Ph.D degree in Applied Statistics from the Polytechnic Institute on N. Y. and his masters degree in statistics from BYU He worked as a statistician, and later senior biostatistician at Johnson and Johnson Corporation; and as a senior statistician, and later manager of statistical services at FMC corporation prior to returning to academia. He teaches courses on experimental design and quality control and consults with clients through the BYU Center for Statistical Consultation and Collaborative Research.

John Erjavec—is a retired Professor and Chair of the Department of Chemical Engineering at the University of North Dakota (UND) where he taught for 20 years. He obtained his B.S in chemical engineering at Princeton University, and his M.S. and Ph.D in chemical engineering at the University of Wisconsin, Madison. He minored in statistics while getting his Ph.D., and his Ph.D. research was motivated by a desire to show the power of some new statistical tools in experimental design and analysis to modeling in the sciences and engineering. The principal investigator on that project was G.E.P Box, a professor in the Department of Statistics. Dr. Erjavec worked for five years at American Cyanamid as a process analysis engineer, and followed that with ten years at FMC Corporation. His titles at FMC included Senior Statistician and Manager, Systems Analysis. While at Cyanamid and FMC he taught (with John Lawson at FMC) numerous short courses in experimental design and data analysis to engineers and scientists throughout the company. At UND he continued teaching (in addition to the usual chemical engineering courses) engineering statistics to seniors in engineering and graduate students in both sciences and engineering.