QUALITY SCIENCES AT DELCO ELECTRONICS CORP.

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Introduction
Delco Electronics Corp. is a subsidiary of GM Hughes Electronics and is responsible for the computer related components in General Motors trucks and automobiles. This makes them the largest manufacturer of computers in the world. They designed and manufactured the navigational guidance systems for the Command Module and the Lunar Excursion Module. They provided the Lunar Rover Vehicle and more recently the LANTIRN project for the Gulf War. In addition to supplying engine control modules, radios, and instrument panels for General Motors, they are a recognized quality supplier to Ford, Chrysler, the Department of Defense, and to some foreign automobile manufacturers. They have plants in Indiana, Wisconsin, Michigan, California, Mexico, Singapore, and England. In 1981, they retained McElrath and Associates Inc. (MAI) to implement a Total Quality System (TQS). Gayle McElrath provided part-time statisticians, and full-time Resident Consultants to provide this implementation. Delco Electronics Corp. provided the facilities, a secretary, and a management style that allowed the marriage to flourish. The complete TQS program provides for managing for quality, cost of quality, and the technology for quality.

The home office of Delco Electronics Corp. is in Kokomo, Indiana and supports a full-time manager for quality sciences and a classroom that is dedicated to the teaching of the technology for quality. Professor Associates teach for a half-day and are available for assisting students or consulting the other half. Two instructors are brought in on most days so there is always someone available for consulting. The MAI faculty and the Quality Sciences Manager have developed a working library of teaching tools and resources that is available to all Delco employees. There is also a library of more than eight-hundred employee projects that represents numerous success stories.

Purpose
Delco Electronics Corp. states that the purpose for providing the MAI training is fourfold: 1) Promote the quantitative analysis and decision making for quality improvement. 2) Develop a common language. 3) Develop a sound technical foundation in the design, manufacture, and service of products. 4) Develop personnel resources as change agents for effective application of statistical techniques.

Product decisions require supporting data. Delco recognizes the responsibility of proving their processes are capable and Delco contracts go first to the suppliers that have capable processes. More and more employees turn to control charts, capability studies, and design of experiments to prevent potential problems. Because the majority of their products are sold to internal customers, Delco is not eligible to compete for the Malcolm Baldrige award. However, they have recently received the top rating in the "Internal Customer Satisfaction Survey". This survey is a measure of quality, reliability, delivery, and technology as defined by their internal customers.

Courses
The first course offered, an overview of the training and implementation to come, is called Managing for Quality and Reliability (MFQR). This is a four day seminar designed for top managers and those employees that will be going through the technology courses. Two days are aimed at managing for quality and reliability and two days are devoted to the technology of quality. The obvious benefit is to start the germination of a common language and a procedural philosophy for all of the employees. This class is taught by members of the MAI staff experienced with management training. This is followed by the technology classes, Quality Engineering (Q.E.) I and II. Each of these classes is twelve weeks in length and meets once a week for three hours in the plant. The instructor collects and grades the homework that is assigned weekly. An in-plant team project is required for the completion of each course.

Delco Electronics Corp. employees that were successful at Q.E. I and II and demonstrated good teaching skills were tapped to train hourly and line supervisors. They taught an eight week course similar to Q.E. I where the theory was reduced and the implementation was strengthened. Some were even certified by MAI to teach Q.E. I. Some sampling remains, but the emphasis of Q.E. I is on the understanding and use of control charts, gauge repeatability and reproducibility, and conducting capability studies. To obtain world class quality, continuous variable charts have replaced attribute charts whenever feasible. Q.E. I is open to all employees, but is strongly recommended for engineers and those in purchasing. Half-way through the course, students break up into teams of two to four and select an in-plant project. These teams present a proposal for their intended project to the instructor and to their supervisor. After a proposal has been approved, each team meets with the instructor and plans the design of the project. Once the data has been collected, the instructor reviews the students' analysis and offers suggestions. On the last day of class the teams present their projects to their peers, supervisors, and instructor. Those that attend 75% of the classes, do all of the homework, and present a project are awarded Q.E. I diplomas. Many of Delco's control charts originated as Q.E. I projects and the use of capability indices is now a

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Q.E. II introduces the student to inferential statistics. The student learns to test for differences in population means and variances. The determination of sample sizes and the understanding of operating characteristic (OC) curves are also included. They are encouraged to run an experiment on an in-plant process that will result in centering the mean and/or reducing the variability of a given process. The course duration and requirements are identical to those of Q.E. I. The teaching of SAS® software was not originally included in these two classes. Today, the SAS software training begins with Q.E. II.

The student learns about PROC MEANS for paired t-tests and PROC TTTEST for analyzing two populations with unknown variances, either equal or unequal. PROC GLM and PROC ANOVA are used for analyzing more than two populations. PROC MEANS and UNIFORM are used for generating random numbers and PROBIT for confidence intervals with known variance. Students learn about OUTPUT, PROC PRINT, TITLE, PROC PLOT, and LABEL. The text for Q.E. I includes PROC CHART for histograms and Pareto diagrams, and PROC UNIVARIATE for reporting the mode and quantiles. When studying probabilities, the text presents PROBHYP, PROBBNML, POISSON, EXP and PROC PLOT. When studying sampling distributions, the students could pick up PROBCHI, PROBT, and PROBF.

In the text book SAS programs are provided for doing control charts, although most are done by hand. Example SAS programs for OC Curves are also provided. The biggest advantage of introducing SAS terminology early is the cultivation of a fear-free Q.E. III class.

Q.E. III is a design of experiments course that has a Q.E. II prerequisite. In the earlier years, SAS software instruction was delayed until this class and for some of the engineers, this was their first exposure to using a computer. The teaching of the earlier classes was hampered by differences that existed in hardware and the fact that the SAS software was only available on the remote mainframe. The faculty used page by page screen dumps to develop handouts that made it possible for the students to become familiar with the different SAS commands and how to move around in the mainframe. The student would follow the screen dumps for the sample problems presented in the text and the student would solve similar problems for homework due the following week. Today, the students are usually well trained in computer usage, and bring to the classroom a desire to push the computer to its limit. It is comforting to know that SAS software has the power to provide the information requested, regardless of the size of the data set or the complexity of the statistical design.

Some of the early year projects were more along the lines of multiple regression. The students would take historical data, use PROC STEPWISE, and arrive at a predicting equation. The most successful one I was associated with was submitted by Curt Erickson at the Milwaukee Plant. Gyros were not meeting specification after they were completely assembled and required an expensive tear down and rebuild. They were failing because of a dependent variable called r-term. Readings had always been taken on the two end housings and on the main housing before the gyro was assembled. Armed with this data and the SAS software, Curt was able to write an equation that would predict r-term before the gyro was assembled. Because of the circular nature of the product, it was not surprising that the final equation had squares and products of some of the independent variables in it. In production, the components are not assembled now if the predicting equation suggests that the product will fail because of r-term. The pieces are shelved until matching components are produced that will guarantee an acceptable r-term. Having eliminated failure due to r-term, the problem of too many shelved and housings had to be solved. By this time, the Taguchi influence had caught hold, and more of the projects centered on a true design of experiments. Thus another project by Ishrafl and Griessmaier was conducted. Their experiment indicated the concentricities of the end housings could be changed to the directions needed by the majority of the main housings being produced.

Today, virtually all of the projects involve a true design using PROC GLM initially, and then PROC STEPWISE if needed. The early decision was made to do all of the teaching with PROC GLM to reduce the necessary vocabulary required to run the ANOVAs. It has been exciting to see the techniques also applied in the design of new products. A recent one was a project by students Fye, Sanders, Schubert, and Schertz in Kokomo. Worrying about the reliability of a formed applique material it was decided to expose plastic corners with four different radii in solutions that were used to predict internal stress. PROC GLM and PROC STEPWISE was used to find the best radius to reduce internal stress on the product. This is a case where Delco Electronics Corp. has met the customer's needs before production begins.

Q.E. IV, Taguchi Engineering, and Reliability Engineering (R.E.) I have also been added to the curriculum as needed. The first two have a Q.E. III prerequisite and serve as a review. They also include topics that have not been covered in the other courses. The Taguchi class presents the Taguchi philosophy and adds the signal/noise ratio, robust designs, loss functions, and cumulative analysis. R.E. I is an eleven week introduction to Reliability Engineering. It uses an instructor developed notebook and a reference text. The course covers the basic concepts of reliability and the techniques of reliability engineering. Included are the normal, exponential, Weibull, log normal, and the binomial distributions. Also included are reliability prediction and allocation, reliability testing, and some maintainability.

Text Materials
McElrath and Associates, Inc. brought to Delco Electronics self-developed texts that had been field tested.
with other clients for teaching O.E. I and II. However, a new text was designed and new materials were prepared with the aid of a computer and a laser printer. The recently finished text is called, *Industrial Statistics* by Bernard Ostle, Charles R. Hicks, Gayle W. McElrath, and Kenneth V. Turner Jr. The text has a publisher and should be in print by 1993. The SAS commands, mentioned above, are nicely woven throughout the entire text. *Fundamental Concepts in the Design of Experiments* by Charles R. Hicks and published by Holt, Rinehart, and Winston is used to teach O.E. III and parts of O.E. IV. The next edition of this text will also include the necessary SAS commands. The SAS commands with examples have now been bound and passed out for student use. *Taguchi Techniques for Quality Engineering* by Phillip J. Ross and published by McGraw Hill is used for the Taguchi Engineering class. *Practical Reliability Engineering* by Patrick D. T. O'Connor, published by John Wiley and Sons, is used as a reference text for R.E. I. *SAS Applications for Quality Engineering* III Quality Engineering IV and *Taguchi Engineering* by McElrath and Associates, Inc. is a 134 page document prepared for Delco Electronics classes.

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