Laboratory 5 – Univariate Data
Assigned Week of October 31, 2011
Due Week of November 7, 2011

I — Introduction:

Engineering measurements and the statistical nature of measured data are basic to all engineering disciplines. Univariate (single parameter) measurement is the focus of this laboratory exercise.

Technological problems can be approached with experience or with engineering expertise. Indeed experience is the basis of many technological solutions. For example, most home building is the responsibility of practitioners with considerable experience in the industry. For the most part engineers are not directly involved in single-family low-rise home building because it is not necessary. Low-rise structures are generally safe and society trusts contractors and builders to do the job.

However, when a building exceeds three stories, experience in not enough. Society does not trust practitioners with only experience to build high-rise buildings. In fact, it is the law that "professional engineers" with a "certificate of authorization" in the structural area, must design any building over three stories. So, what is it about engineering that warrants this kind of special trust and responsibility? It must be that engineers provide skills other than experience to deal such situations. The general understanding is that engineers use applied science to address problems of this kind. That understanding is valid as far as it goes—but there is a great deal more to it than that.

Engineers model technological problems to find practical solutions. Applied science is basic to the model approach to be sure, but generally applied science alone is not enough to assure the safety of a high-rise building. For starters, measured data are essential inputs when evaluating science-based mathematical high-rise building models. For example, if it is a steel structure, the strength of the steel beams used must be known from measurements. But even this is not enough. By and large, there are many approximations and assumptions that have to be incorporated in any real life engineering model. The significance of such approximations and assumptions is evaluated on the basis of engineering judgment, which in turn is based, at least in part, on laboratory and field measurements.

While a "civil engineering" example has been used to illustrate the need for an understanding of measurements and data in this discussion, there are equally compelling examples in all other engineering disciplines. It is, therefore, essential to develop an understanding of the statistical nature of measurements and data, and to fully appreciate the concept of data significance. We begin by considering univariate (single parameter) measurements and processing.

II — Problem Statement:

At Kennedy Space Center in Florida, the skies were clear and the sun shone on the day that the *Challenger* was scheduled to launch. This was the 25th space shuttle mission and the 10th flight of Orbiter *Challenger*. This launch was one of the most publicized launches as it had the first civilian (Christa McAuliffe, a 37 year-old school teacher and mother of two) on board. On the morning of January 28, 1986, the weather was colder than any other day that NASA had launched a space shuttle. At 11:38 A.M.

Eastern Standard Time, the Challenger lifted from Pad 39B at Kennedy. Seventy three seconds into the flight, the shuttle exploded killing all seven astronauts on board. The rocket was traveling at Mach 1.92 at an altitude of 46 000 feet (about 14 021 metres) at the moment it exploded.

Figure 1: The *Challenger* explosion, January 28, 1986.

Table 1: O-ring temperature (°F) for 36 launches of the space shuttle rocket engine

84	49	61	40	83	67	45	66	70	69	80	58
68	60	67	72	73	70	57	31	70	78	52	67
53	67	75	61	70	81	76	79	75	76	58	63

The tragedy led to a number of studies investigating the reasons for mission failure. Attention quickly focused on the behaviour of the rocket engine's O-rings, which are loops of elastomer with a round (O-shaped) cross-section used as mechanical seals or gaskets. They are designed to be seated in a groove and compressed during assembly between two or more parts, creating a seal at the interface. Table 1 presents a list of O-ring ambient temperatures (°F) prior to test firings or actual launches of the shuttle (including the disastrous *Challenger* mission) – these are the temperatures of the surroundings at the time of tests or launches. It was later found that the failure of the solid rocket booster O-rings allowed hot combustion gases to leak from the side of the booster and burn through the external fuel tank, which led to the explosion. It was known that the O-ring could be expected to fail in cold temperatures, but the launch had been already delayed five times, and so the people in charge of the mission "took off their engineering hats and put on their management hats".

Without any statistical inspection of the sample data, none of the conclusions regarding the significance of the O-ring temperature in the disaster could have been made. In the given form it is difficult to get a sense of what a typical, or representative temperature might be: whether the values are highly concentrated about a typical value or quite spread out; whether there are any gaps in the data; what percentage of the values are in the 60's, and so on. Detailed techniques for obtaining all of that information (and much more) will be taught to you in a separate course in third year — STAT 3502 "Probability and Statistics". For now, you are to simply analyse these sample measurements to obtain a sample mean, a sample standard deviation, a standard error, and the 90% confidence limits. In addition, you must graphically represent the data in the form of a histogram.

III — Steps and Calculations:

1. For the sample data presented in Table 1 construct a relative frequency table and then plot a relative frequency histogram (refer to your textbook for help using Excel). Use 14 classes or bins (each of width 4), starting your first bin at 32 °F (that is bin 1 is all temperatures <32 °F, bin 2 is all temperatures 33 to 36 °F, and so on).

2. Describe the shape of the obtained distribution. Is it normal? Is it skewed? Does the sample have any obvious outliers?

3. Judging from the histogram, what was the temperature of the engine's O-ring corresponding to the catastrophic launch of the *Challenger*?

4. Eliminate the Challenger low temperature data point from the data set and then determine the following for the remaining data as described below:

   (a) the sample mean;
   (b) the sample variance and standard deviation;
   (c) the standard error;
   (d) the estimate of the true (population) mean at 90% confidence level (i.e., determine the 90% confidence interval for the true mean).

   Determine all quantities (a) to (d) above in two ways:
   - Use the appropriate equations and the "z" tables to determine the confidence interval. The formulas and tables are in the class notes and Chapters 18 and 19 of your textbook. You may, if you wish, use a spreadsheet program (e.g., Excel) to assist you with the computations.
   - Determine these same parameters, (a) to (d), with the Excel tool: "Data Analysis" (Descriptive Statistics).

     ➢ The results determined with these two methods will be included in a summary table along with the results of step 5 below.

5. Use the sample mean and the sample standard deviation calculated in Step 4 to generate a random set of normally distributed data (35 numbers) with Excel's "Random Number Generation" function. Select "normal" for distribution and use the last three numbers of your student number as the random seed variable. For your random data, determine the parameters (a) to (d) in step four above – you can choose whether to use the formulas or the Excel data analysis tool, but remember to record your choice.

➢ For your report you will generate a summary table of the results of steps 4 and 5, and then compare these results. In addition, you will discuss any differences you observe. The summary table will look like the table on the next page.

Summary Table: [REPORT ALL NUMBERS IN THE TABLE TO THREE SIGNIFICANT FIGURES]

Sample Statistic	Result via equations	Result via MS Excel	Random Normal Distribution using Excel with seed = “insert last 3 numbers of your student number”
Mean			
Sample Variance			
Standard Deviation			
Standard Error			
Population Mean with 90% Confidence Interval			

IV — Report Requirements:

- Using the guidelines presented in Laboratory 1, produce a formal laboratory report that summarizes your findings.

- In the “Results and Discussion” of the report, state the mean, the standard deviation, the standard error and the 90% confidence limits for the sample. Comment on any differences in the summary table between the statistics determined for the temperature data with the two methods in Step 4 (using the equations and Excel’s data tools, i.e., the numbers in the second and third columns). Discuss the significance of these statistics to the study of the *Challenger* disaster. Comment on Steps 2 and 3 of Section III above. Comment on any differences between the statistics determined for the data that were randomly generated and the statistics determined for the provided data? What are your conclusions? Did you fulfill the objective? Be as specific as possible.

- Include your calculations along with any formulae (MS Equation Editor) you used, as well as present your random generated sample in the appendix(ces).
- Keep in mind that the entire written report is to be limited to a title page, a one-page report and appendices for figures, tables and graphs, etc. All pages are to be well organized. Use 12-point font text with 2.5 cm margins all around.

V — Submission and Timing:

Your report is to be submitted to the Teaching Assistant within the first 30 minutes of your next laboratory period (week of November 7, 2011). **LATE SUBMISSIONS WILL NOT BE ACCEPTED.**

VI — Marking:

Laboratory submissions will be marked on a 10-point scale: 9-10 (excellent); 7-8 (good); 5-6 (marginal); less than 5 (fail). **Be sure that you are familiar with the University’s policy on plagiarism and academic integrity. Your instructors are obligated to report all suspected violations to the Associate Dean’s office for investigation.**