To: ENRG 132 project teams
From: Frank O. Simpson, President, First-Order Systems, Inc.
Date: April 1, 2019
Re: Data analysis for a new client

First-Order Systems, Inc.
An Engineering Company

Your ENGR 132 instructor reports that you are making good progress on algorithm development, and you have tested your algorithm against the heating and cooling calibration datasets provided to you. This is good news and it appears that you are now ready to perform parameter identification with datasets from our in-house testing.

We have a new client, Swiss Chocolatiers of Greater Lafayette (SCGL), and they have asked us to provide thermocouples to monitor chocolate temperatures throughout their manufacturing processes. In particular, there is one step of the chocolate making process called 'tempering' for which temperature control is crucial. Chocolate is heated to 115 ^{o}F to completely dissolve any crystals that have formed in it, then it is cooled to 94 ^{o}F to allow the formation of the specific, desirable crystals that give the chocolate its texture, mouth feel, the characteristic 'snap' of a chocolate bar, and ensure that it does not melt in your hand. So obviously this tempering process is a crucial part of chocolate manufacturing. There are plenty of online sources that further explain tempering, but remember that SCGL tempers their chocolate at very large scale in the local manufacturing and processing plant. They need careful and accurate temperature measurements to ensure that their processes are working as planned.

We have worked with your ENGR 132 instructors to provide you with 100 time histories: 20 experiments with each of 5 thermocouple designs. For each set of 20 experiments, 10 use the heating condition, and 10 use the cooling condition. The heating condition corresponds to the heating portion of the tempering process: starting at 60 ^{o}F and heating up to 115 ^{o}F. The cooling condition corresponds to the second tempering step: cooling the chocolate from 115 ^{o}F to 94 ^{o}F. The 5 thermocouple designs are distinct, and the easiest way to think about their differences is in terms of cost. Thermocouples with a fast time constant are more expensive than those with a slow time constant. Our current plans are to offer our thermocouples to SCGL at the following unit prices (i.e., price per thermocouple):

Model Number	Unit Price ($)
FOS-1	15.83
FOS-2	8.52
FOS-3	3.50
FOS-4	2.03
FOS-5	0.65

We would like you *to build a regression model* that helps us understand thermocouple price as a function of performance (time constant) in this important, practical application. If we can understand this relationship, we at FOS can do several things: (i) build better thermocouples that are competitive with others in the marketplace for food processing applications such as those used at SCGL, (ii) identify the best pricing strategy to position our products for high sales volume in the food processing market sector, and (iii) create honest sales literature that accurately reflects the performance and value of our products.

It is crucial for us to understand the behavior of the 20 thermocouples within each design, so we are asking you to calculate some basic statistics (mean, standard deviation) about the time constant for each of the five designs.

The time histories are contained in two CSV data files that you can download from your Blackboard site called 'heating_time_histories.csv' and 'cooling_time_histories.csv'. The 51 columns in each data file are organized as follows:

- Column 1: the time vector for each time history
- Columns 2-11: 20 experimental time histories for model FOS-1
- Columns 12-21: 20 experimental time histories for model FOS-2
- Columns 22-31: 20 experimental time histories for model FOS-3
- Columns 32-41: 20 experimental time histories for model FOS-4
- Columns 42-51: 20 experimental time histories for model FOS-5

You job is to analyze all of these heating and cooling time histories, and *aggregate the results for each model of thermocouple we make*. You will report the results of your analysis to us using the answer sheet your instructor has constructed for you. We are especially interested in the regression model of price and time constant, and also your observations about how your algorithm might be improved for future analysis.

We appreciate your on-going help with this project, and we eagerly await the results of your analysis.