Failure Is Not an Option in Educating Tomorrow's Engineer

Gregory Thompson

"Failure is not an option." These words were uttered by Gene Kranz, NASA Flight Director, during the *Apollo XIII* flight that nearly ended in catastrophe. Unfortunately, with any major engineering endeavor, failure because of the intrinsic characteristics of a material and/or decision-making can only be minimized, but not eliminated. Most recently we have been reminded of this with the *Deepwater Horizon* oil spill in the Gulf of Mexico. As an educator, I am conscious of the need to teach our next-generation engineers the skills to avoid such incidents. Future engineers must be educated about materials design and its relationship to engineering risk management.

Properties, and therefore performance, of materials are often controlled by microstructural features and defects. Within materials, these features and defects, such as size and spatial location, have a distribution. A classic example of materials properties that are governed by a distribution is mechanical behavior. Bulk strength is associated with the mean of the distribution whereas crack initiation, or failure, is governed by the tails of the distribution. Engineering safety or reliability can focus on reducing the outliers (i.e., the weakest events) by narrowing the distribution toward the mean. In some cases, the mean may not be able to be optimized much further; consequently, the outliers, or tails, of the distributions would be the focus of investigation for materials improvement. An engineering challenge is how to detect those outliers in these tails and determine

when and how they cause a disruption. A grander challenge is if these tails themselves can be engineered. To do this, what skill set will an engineer need?

Engineers have to be able to collect data from multiple inputs, assemble this data in a useful arrangement, use the information to identify the problem, and propose a solution. First and foremost in these steps, the engineer should inquire "am I asking or solving the correct problem?" Once answered, the engineer can focus appropriate tests to understand the materials design interactions. When engineering the tails, identifying the outliers can be challenging since they are rare by definition. Data mining is one methodology that can be undertaken to possibly observe these 'singularities' and correlate them to a property or process. If outliers are observed, the engineer must critically evaluate if the data points are real and reproducible. Do the statistic tests applied to the test evaluation make sense? If so, how is the risk associated with that observation assigned? These are all critical questions that engineers must address.

While we can collect much data through our tests, another challenge is our ability to recognize trends. While traditional methods of correlation using two-dimensional plots are still very useful, methods such as Principle Component Analysis can allow even more detailed correlations to be detected. This will take on greater significance as data sets become larger and more multidimensional. Consequently, the rising generation of materials engineers will be required to have an even stronger grasp of statistics to use these tools.

Though new and exotic forms of re-

presentation of large data sets will come, engineers will still need to explain and represent data in a simple and concise manner to the lay public. In doing so, informed decisions can be made. In Edward Tufte's *Visual Explanation*, the 1986 *Challenger* disaster is discussed. Though the data was present to avoid the catastrophe, it was never presented in a manner where the problem was recognized. Good communication skills are essential as engineering continues to move to larger data collection and analysis tools.

Finally, what role does TMS have in these challenges? Our society can play a vital role in the education of its members and the public. As the leading materials engineering organization, we understand more than most the impact of the tails. Through our symposium topics, workshops, publications, and forums we can develop both the technical and nontechnical tools for our workforce to meet these needs.

The engineers of tomorrow not only need to grasp complex technical topics and analyze large data sets, they may be required to translate these complicated concepts and conclusions to a nontechnical audience. By increasing their exposure to statistical methods and clear communication techniques, their ability to responsibly address outliers in engineering will be improved. Though these outliers may be few and far between, their impact on materials performance cannot be underestimated. Educating tomorrow's engineer with these skills will help to initiate new areas of materials engineering.

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