EDITORIAL

Insight – Not Numbers

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In 2006, a *Wall Street Journal* analysis of executive stock option grants concluded that backdating of options had occurred. Analysts looked at the stock price of various companies for the 20 trading days after the date of a grant compared to all other 20-day trading periods over a year. They discovered that, repeatedly, for a number of executives at companies they examined, the options were dated at a time when the stock price was at its relative lowest, making the grants more valuable. The analysis concluded that the odds of this happening by chance were approximately 1 in 300 billion. After the article, discovery of stock option backdating reportedly forced some 70 CEOs and other corporate officials to resign or be fired, with the U.S. Securities and Exchange Commission investigating possible option backdating at more than 150 companies.

While there may have been suspicions regarding the timing of these executive stock options, simply looking at the "numbers" – the option price, change in stock price over time, profits – was not enough to establish that something untoward had taken place. The insight came from using computers and probability techniques to do a thorough statistical analysis. The insight gained from the analysis, not simply the numbers, is what led to the understanding of what had actually taken place and is what resulted in punitive action.

By the way, credit for the phrase, "Insight, Not Numbers," goes to my friend Håvard Vold for his 1989 IMAC keynote paper and address and to his source, a 1962 numerical methods book by Richard Hamming.

As engineers, we deal with numbers every day, and not just at work. We take measurements, build computer models, make budgets, plan schedules, and create forecasts. We pay bills, balance our checkbooks and try to figure out how much to save for retirement. Like me, maybe you have kids in college. You're not only trying to pay for it but also trying to teach your young adult offspring how to make a budget and then live on it.

When and how does learning take place? Do we learn from the numbers (I say 'no') or from the interpretation of the numbers ('yes'), and if so, what are the keys to gaining that insight? Ironically, in this age of more, faster, better, I think the short answer is less and slower. I mean fewer numbers and taking more time to study, interpret, and understand. Yes, computers allow us to do many things faster and easier. In five minutes, we can compose and send an e-mail to dozens or hundreds, but have we improved our ability to communicate from that not-so-distant time when we used a typewriter to construct a letter or memo, the copier to duplicate it, and the mail to send it? In those pre-computer days, I spent more time thinking through the content of the communication, knowing that if I were unclear, it would take considerable effort to correct it.

Does more data mean more understanding? Not long ago my colleagues at UGS (now Siemens) claimed to have performed an analysis on the largest-ever, finite-element model – 200 million degrees of freedom (DOF). The linear static analysis was performed in NX Nastran to simulate the behavior of an airplane wing structure under shear load conditions. They claim they will soon be able to solve similar problems up to a billion degrees of freedom. That's very impressive. But I would be more impressed if an engineer could tell me what he can learn from this larger model that wasn't possible a while back when he was limited to perhaps 100,000 DOF.

When I began work at SDRC (Structural Dynamics Research Corporation) as a test engineer, my real learning began. While "in the field," we often faced equipment vibration problems; it was our job as consultants to understand and fix them. Our equipment consisted of a few accelerometers, an oscilloscope, a tape recorder, strip chart, and our almost magical Spectral Dynamics Real Time Analyzer – it really was a black box! I particularly liked the oscilloscope and the ability to see vibration response in real time (as well as the effects of noise, ground loops, cable motion, transducer malfunctions, amplifier saturations, DC offsets, the other machinery operating nearby and more).

Often we were concerned with displacement, even though we typically measured acceleration. One common formula that we used to compute displacement is $D = 10A/F^2$ where: D = displacement (in), A = acceleration (g) and F = frequency (Hz). Can you write the exact formula knowing that 1 g = 386 in/second-squared? Remember that this formula is particularly useful when responding to an analyst who says he needs you to run a vibration test to 10 g at 2 Hz.

I took a special liking to modal testing and enjoyed helping advance acceptance of multiple-input, random-excitation methods. But it wasn't until I could derive the formula for a frequency response function (FRF) that the insight occurred. I appreciated the mentoring of the more experienced SDRC people who taught me things I probably should have learned in school. For anyone reading this who is involved in measuring a FRF, I encourage you to find the basic formula for a proportional viscous damped system and see for yourself why the FRF looks like it does. And why, for example, a "driving-point" FRF (input and output locations are identical) has phase changes limited to 180 degrees with alternating resonances and anti-resonances.

In my early days of modal testing, we monitored every transducer on the oscilloscope (not hard to do when we were limited to 4, 8, or 16 channels) and reviewed every FRF (and coherence) before saving and moving on. And we spent a lot of time trying to improve the reciprocity FRF, knowing our ability to extract very clean modes depended a lot on the quality of measured data. Today, extracting modes from an FRF tends to be more automated. Rather than examining individual FRFs or fitting one mode at a time, an engineer may use a high-tech Polyreference technique to "curve-fit" a massive amount of data. The resulting mode shapes may be accepted as final results without further validation.

The data collection systems offered commercially today make data collection all too easy. The hardware/software manages large numbers of channels, generates the signals to drive the exciters, has a wide range of graphical displays, performs digital filtering and decimation when needed, and generally possesses the capability to automate most aspects of the data acquisition process. In effect, it is easier than ever to collect large amounts of erroneous data in no time!

A major problem is that with so many input channels, it is very easy (and tempting) not to inspect each and every measurement. It is not difficult to miss overloads that may occur, ignore an input voltage range that is too high or too low, apply the wrong window on the data, etc. On more than one commercial system, automatic overload detection and rejection are either poorly implemented or not implemented at all. More than ever, the test engineer needs to be fully attentive and cognizant of what the data acquisition system is doing.

As my career has evolved, I sadly find that I don't get to participate in many modal tests. But fortunately I discovered another passion – spreadsheets! Excel is now my favorite software tool, and while it's not as cool as Modal-Plus, when it comes to turning numbers into insight, it's almost as powerful. Why, just yesterday I was able to chart my gas mileage for the past two years as a function of cost of the gas. I had known for some time that driving my car at 80 miles per hour instead of 65 would lower my miles per gallon. But it wasn't until gas prices went way up that I decided to pay attention to the needle on my MPG indicator, not just the average MPG readout. On one chart, I now had the proof – or insight – that the increased cost of gas had made no difference whatsoever in my driving habits. Only the speeding ticket I received last month had caused me to slow down. At least for now. I encourage you to do the same – and to spend some time looking beyond the numbers. SV

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