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BOOK REVIEW

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Review of: *Uncertainty Analysis for Forensic Science*

REFERENCE: Brach RM, Dunn PF. Uncertainty analysis for forensic science. Tucson, AZ: Lawyers and Judges Publishing Company; 2004.

Uncertainty Analysis is a well-established, fairly complex, mathematical, statistical toolkit that is utilized to assess the "accuracy" of measurements and calculated results. In Forensics, Uncertainty Analysis can be—but, because of its complexity, is not—routinely used to assess the assertion of Reasonable [*pick a field*] Certainty with respect to an opinion or a conclusion propounded in a report or in testimony.

Unfortunately, *Uncertainty Analysis for Forensic Science*, by Brach and Dunn, is unlikely to change that. The short of it is that the book is a typo-laden summary of Uncertainty Analysis *For* Uncertainty Analysts, with mathematical analysis *far* beyond many forensic engineers (let alone judges and lawyers, who also need to understand this business), and with examples having perhaps a forensic context, but with little of the insight needed to actually use Uncertainty Analysis in litigation. The short of it is that I would not recommend this book to those interested in the field, at least until a revised edition is put out that corrects the myriad typos and copy-editing glitches. Even then, be prepared to slog through this book, and be prepared to supply your own context. There is a real need for a book to take on this topic in a way that would be meaningful to forensic practitioners—so that Daubert/Kumho proceedings could turn into more than a list of check box, jump-through-hoops maneuvers—but *Uncertainty Analysis for Forensic Science* is simply not that book. The details are below.

Here is a remarkably brief summary of Uncertainty Analysis. There are different kinds of numbers, representing fundamentally different concepts, something we all learned in junior high school. For example, there is a huge difference between the number two, as in two children, and the number two, as in 2 in. The former number represents a counting process (one child, two children, "I-am-the-Count-because-I-love-to-count" (from-Sesame-Street), three children, . . .) while the latter number represents a measurement process. While counts and measurements may be subject to error, *all* measurements are subject to uncertainty. Uncertainty is not error. Uncertainty is due to the fact that measurements can be made to whatever accuracy you choose to make them. When we say a person is 72 in. tall, we do not mean that that person is 72.0000000000000000 . . . in. tall; rather, we mean that that person is 72 in. tall to the nearest inch: $72 \pm 1/2$ in. That $\pm 1/2$ in. expresses in a very simplified form, what we do *not* know about the height of the person: the uncertainty, more or less. We could measure that same person more carefully, with more sophisticated equipment, and find that person to be 72.2 in. tall, which means 72.2 ± 0.05 in., cutting what we don't know by a factor of 10.

What does this have to do with Forensic Science? Simply, that every measurement, and every result based upon measurements that comes up in a litigation, is subject to at least some degree of "fuzziness." Uncertainty Analysis supplies the tools that you use to characterize measurement "accuracy," and to calculate that "accuracy" of a formula result, when measurements are used as inputs to a formula. Thus, uncertainty analysis in Forensic Science can help determine whether measurements, and results calculated from measurements, are capable of proving (or disproving) a point that one would like to prove (or disprove) in a litigation. Much, may be most, of the time, the uncertainty in the measurements is such that it would have no practical effect upon the drawn conclusions, e.g., a car proceeding on the interstate at a measured or calculated 100 ± 20 miles/h is *obviously* speeding if the speed limit is 75 miles/h. Sometimes, the uncertainty can have an important impact in the conclusions. A car proceeding on that same interstate at a measured or calculated 90 ± 20 miles/h speed may or may not have been speeding if the limit was (again) 75. Importantly, the conclusion that the latter car was speeding may not be able to be made to within a reasonable degree of certainty based upon engineering (or accident reconstruction) analysis. Even the most rudimentary Uncertainty Analysis would make clear that when your calculator displays 89.823456789 (miles/h), an analyst would be foolishly wrong not to round the result to 90 if the uncertainty was ± 20 miles/h.

Uncertainty Analysis for Forensic Science is organized into an introduction and five chapters, and has a rather comprehensive table of conversion factors (from abamperes-to-amperes to year-to-seconds) in the appendix. The five chapters are:

- Units, dimensions, significant figures, and calculations.
- Probability and statistics.
- Uncertainty analysis.
- Uncertainty analysis using statistics.
- Sensitivity and design of experiments.

The Units chapter contains material that most technical people at one time or another did know. If you did not study technical stuff

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in college, this material may well be new to you. For some this material will be a steep climb. It doesn't help that typos, obvious I think, to those who are at least somewhat familiar with the material (J/m3 instead of J/m^3, K–273.15+°C instead of K = 273.15+°C), or a sentence that refers to "in the previous example of determining the weight of the ingot . . . " and then, a bit later, but without a paragraph break, "For example, if the uncertainty in the measurement is 0.05, then the measurement should be expressed with the same precision, such as 1.23 ± 0.05," when the 1.23 ± 0.05 doesn't refer to the ingot example; it's a completely separate thought. (Things like punctuation give clarity to thought. In a highly technical work such as this, the careless copy-editing adds immeasurably to the difficulty of *learning* the material.)

The Probability and Statistics chapter is essentially a rehash of what one would see in an advanced undergraduate or graduate probability and statistics course given to statistics majors. The chapter squeezes into 55 or so pages the contents of a multi-hundred-page textbook. If you know the subject, you will find it a not-very-interesting, Cliff-Notes type review. If you don't already know probability and statistics, reading this chapter will be (like much of the rest of the book) like climbing a glass pole with your fingernails. At best, it will be very unpleasant; most likely, you will never get your feet off the ground. The examples, while sounding forensic (Using Bayes' Law, what's the chance a given type of handgun was used in a crime?), completely lack context. This kind of analysis, for example, in the real forensic world, is useful for showing that something is more common than it appears on its face, but would be difficult to use to affirmatively prove something. The book is silent on this. Again, in this chapter, there are obvious errors, such as showing a graph and discussing the two different representations as denoted by open circles and x-marks, when there are no x-marks; it is actually open circles and open squares. Again, those who already know what's going on will say, "Well, DUH . . . ," those who don't will simply be confused.

Rather than go chapter-by-chapter, let me just write that the other chapters are more of the same. It's more productive to discuss what isn't touched upon. There are issues in Uncertainty Analysis that are important in the forensic science context that are completely absent in *Uncertainty Analysis for Forensic Science*. Three obvious examples are (a) issues of correlations between variables, confounding results, (b) dealing with the effect of uncertainty analysis when the result is categorical in nature (Did Joe pull the trigger? (Yes/No) rather than numeric, and (c) worst-case analysis. As to the former, it is the nature of eyewitness estimates of things like time and distance to be correlated, e.g., a witness (eyewitness estimates of things like time and distance are used in much the same way as are actual measurements in litigation) may overestimate all time estimates or underestimate all distance estimates. As the correlation structure can give insight into the overall accuracy of the estimates this is something that, at the very minimum, the book should touch upon. As to (b), much of what is important in litigation is not inherently numeric. (For example, based upon estimates of height, weight, hair length, and other physical characteristics, was the person-of-interest a man or a woman? There do exist tools for the analysis of such things, e.g., logistic regression, and to be fair, much of it is probably too complex for this book. That cannot suggest that the matter cannot be at least discussed.) As to (c), worst-case analysis is quite basic in uncertainty analysis in forensics. It is also rather simple, and goes thus: set each input variable at a value that is both reasonable and disfavors your own client. If you can make your point in that manner, you have essentially put together, with relatively little effort, a cross-examination-proof analysis. That's because any time one varies the input variables, the result comes out *more* favorable to your client. And worst-case analysis obviates the need for things like Monte-Carlo Simulation to determine the probability histogram of the variable of interest.

I am not suggesting that worst-case analysis is a Silver Bullet; many matters need more subtle tools. Rather, I am suggesting that to not mention worst-case analysis (or correlation or dichotomous-result situations) in this book is a serious flaw, a flaw that came about because you cannot simply squeeze the tools of Uncertainty Analysis and all of its precursors into a thin (under 200 pages) book, massage the examples to sound forensic-y, and expect to have a useful-to-the-practitioner product at the end of the process. In short, wait for the second edition, or just take a pass.