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To Lucy

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Preface

There ain't no rules around here –
we're trying to accomplish something!
Thomas Alva Edison

More often than not the discovery of insight begins with intuition. As it is, findings need to be proven by experiment. Paradoxically, the current procedures to verify the conformity between theory and experiment seem to be somewhat out of order and this comes the more seriously into effect the tinier and hence the more delicate to observe the explored effects are. These days physical theories and experiments are more sophisticated than ever. So what is the background of the dilemma?

Metrological data are known to be blurred by the imperfections of the measuring process. All along experimenters attempt to cut out as much information as possible as to the physical quantities aimed at. Here the father figure of error calculus, Carl Friedrich Gauss, is highly esteemed for having put the essentials of data evaluation long ago on a seemingly sound and safe footing. Ironically, Gauss was defeated by a momentous fallacy. The drama has its roots in his proceeding to interpret what he termed *regular or constant errors*, errors being constant in time and unknown with respect to magnitude and sign. As a theoretician Gauss passed the buck to experimenters, claiming that it would be their job to get rid of them. Unfortunately he erred: those errors turned out ineliminable in principle.

As Gauss understood the situation, he based his error calculus on *irregular or random errors* alone, thus creating a concept that was incomplete and, strictly speaking, inapplicable to metrology right from the outset. In retrospect, for about two centuries regular or constant errors were not the focal point of experimental activities. In line with this, today's notation *unknown systematic errors* instead of *regular or constant errors*, as proposed by Gauss himself, suggests that the post-Gaussian era had lost sight of the primordial stimulus given by Gauss.

Confusingly, the worldwide practice to belatedly admit those unknown systematic errors amounts to considering them as being random too. Nevertheless, during the early 1950s and the late 1970s, this so-called *randomization* came under suspicion to cause metrological incompatibilities. Eventually these inquiries suggested considering a rigorous recast of the Gaussian error calculus. Well knowing that any attempt to methodically restructure a constitutive, internationally long established proceeding would provoke intense controversies I realized that that was what had to be done.

In my view the addressed randomization prevents experimenters from localizing the true values of the measurands as the associated measurement uncertainties turn out unreliably small. Furthermore, due to the presence of unknown systematic errors, the common practice to safeguard measurement results by probability statements lacks statistical justification: probability statements regarding measured results do no longer exist.

After all, I conjecture that the conformity between theory and experiment might have become out of balance. That is why this disquisition discusses an error concept dispensing with the common practice of randomizing unknown systematic errors so as to end the current practice of mixing up random errors and randomized unknown systematic errors. Instead, unknown systematic errors will be treated as what they physically are—namely as constants being unknown with respect to magnitude and sign.

For the perpetual localization of the true values of the measurands the term *traceability* has been coined. Obviously, traceability is a necessary condition in order to achieve physical truth, and is hence of paramount importance.

As it stands, the considered ideas issue a proceeding steadily localizing the true values of the measurands and consequently traceability. From there they are likely to offer a way out of the disquiet physics appears to be afflicted with these days.

But unknown systematic errors cause other steep cuts as to scientific reasoning. The tools of statistical inference such as tests of hypothesis and analyses of variance, once supposed to analyse measured data, prove inapplicable in the presence of experimentally induced unknown systematic errors—whether we like it or not.

The reflections might open up new vistas in the natural sciences.

Braunschweig June 2018, *Michael Grabe*

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Author biography

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Dr Michael Grabe studied physics at the Universities of Braunschweig and Stuttgart and took his doctoral degree at the Technical University of Braunschweig, Institute for Physical Chemistry, where he was a research assistant and lecturer for physical chemistry and applied computer science.

He then worked at the Physikalisch–Technische Bundesanstalt Braunschweig, focusing on legal metrology, computerized interferometric length measurements, procedures for the assessment of measurement uncertainties, and adjustments of fundamental constants of physics.

Lectures and papers concerning the evaluation of measured data are cited on http://www.uncertainty.de.