18.4.3.5 Precision and accuracy - related performance characteristics

"Precision" and "accuracy" have thus far been used as general, qualitative descriptors. Such usage is quite common and perhaps even appropriate; however, somewhat different, explicitly defined terms are given below.

Measurement Result

The outcome of an analytical measurement (application of the CMP), or "value attributed to a measurand" (See Section 18.2). This may be the result of direct observation, but more commonly it is given as a statistical estimate $\hat{x}$ derived from a set of observations. The distribution of such estimates (*estimator distribution*) characterizes the CMP, in contrast to a particular estimate, which constitutes an experimental result. Additional characteristics become evident if we represent $\hat{x}$ as follows,

$$\hat{x} = \tau + e = \tau + \Delta + \delta = \mu + \delta \qquad (18.4.8)$$

where:

True Value (τ)

The value x that would result if the CMP were error-free.

Error (e)

The difference between an observed (estimated) value and the true value; i.e., $e = \hat{x} - \tau$ (signed quantity). The total error generally has two components -- bias (Δ) and random error (δ), as indicated above.

Limiting Mean (μ)

The asymptotic value or population mean of the distribution that characterizes the measured quantity; the value that is approached as the number of observations approaches infinity. Modern statistical terminology labels this quantity the *expectation* or *expected value*, $E(\hat{x})$.

Bias (Δ)

The difference between the limiting mean and the true value; i.e., $\Delta = \mu - \tau$ (signed quantity).

Random Error (δ)

The difference between an observed value and the limiting mean; i.e., $\delta = \hat{x} - \mu$ (signed quantity). The random error is governed by the *cumulative distribution function* (*cdf*), which in turn may be described by a specific mathematical function involving one or more parameters. (An example of a one parameter *cdf* is the Poisson distribution, which figures importantly in counting experiments). Most commonly assumed is the normal or "Gaussian" distribution; this has two parameters: the mean μ, and the standard deviation σ. The random error is given by $\delta = z\sigma$, where z is the value of the standard normal variate.

Standard Deviation (σ)

Dispersion parameter for the distribution. That is, σ is the performance characteristic that reflects the root mean square random deviation of the observations (results) about the limiting mean; positive square root of the variance.

Variance ($V = \sigma^2$)

More directly the *cdf* dispersion parameter is the variance, which is defined as the second moment about the mean. For certain non-normal distributions, higher moments may be given.

Systematic Error

Taking Systematic Error to be all error components that are not random, we thus far would equate systematic error with the fixed bias of the CMP. Real CMPs, however, should be described by at least two additional quantities:

-*Blunders* (b) -- which we take as outright mistakes, and
-*Lack of control* ($f(t)$) -- drifts, fluctuations, etc.

Systematic error is defined in the International Vocabulary of Basic and General Terms in Metrology as "a component of the error of measurement which, in the course of a number of measurements of the same measurand, remains constant or varies in a predictable way" (See Section 18.2). A somewhat different perspective on measurement error is presented in the "ISO Guide to the Expression of Uncertainty in Measurement" (See Section 18.8). This alternative view differs from the classical treatment of random and systematic sources of measurement uncertainty, and assigns "standard deviations" to all error components. According to the Guide, "it is assumed that, after correction, … the expected value of the error arising from a systematic effect is zero." A new term, "standard uncertainty" is defined as the "uncertainty of the result of a measurement expressed as a standard deviation." Further, uncertainty components are classified as "type A" and "type B," reflecting those that may be evaluated by statistical methods, and those that are evaluated by other means. Note that the ISO Guide treats *uncertainties of measurement results*, whereas this IUPAC document is concerned with *performance characteristics of measurement processes*.

Imprecision

A quantitative term to describe the (lack of) "precision" of a CMP; identical to the *Standard Deviation*.

Inaccuracy

A quantitative term to describe the (lack of) accuracy of a CMP; comprises the imprecision and the bias. Inaccuracy *must be* viewed as a 2-component quantity (vector); imprecision and bias should never be combined to give a scalar measure for CMP inaccuracy. (One or the other component may, however, be negligible under certain circumstances.) Inaccuracy should not be confused with uncertainty. *Inaccuracy* (imprecision, bias) is characteristic of the *Measurement Process*, whereas *error and uncertainty* are characteristics of a *Result*. (The latter characteristic, of course, derives from the imprecision and bounds for bias of the CMP.)

Note: The resultant bias and imprecision for the overall measurement process generally arise from several individual components, some of which act multiplicatively (eg, sensitivity), and some of which act additively (eg, the blank). (See Section 18.4.3.8)