Language of Specifications

White Paper

What do Specifications Mean?

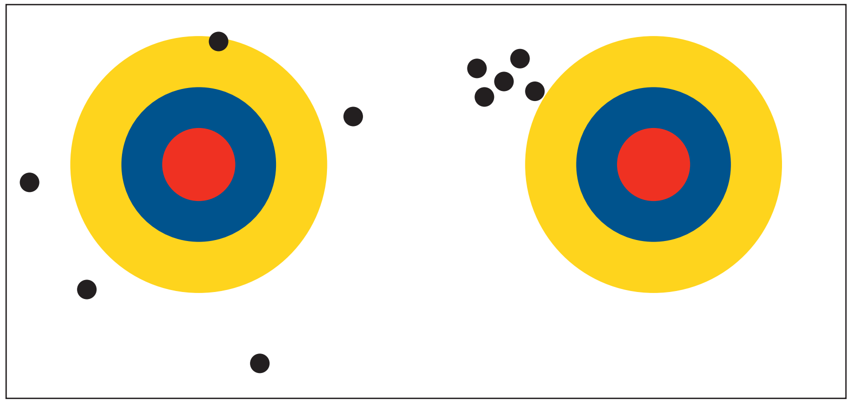
Hitting the Mark

Specifications describe a product's capability but some basic terms are often misunderstood. Has this dart been thrown accurately, or precisely? Is there a difference? This article explains some of the arcane language used in describing a product's characteristics.

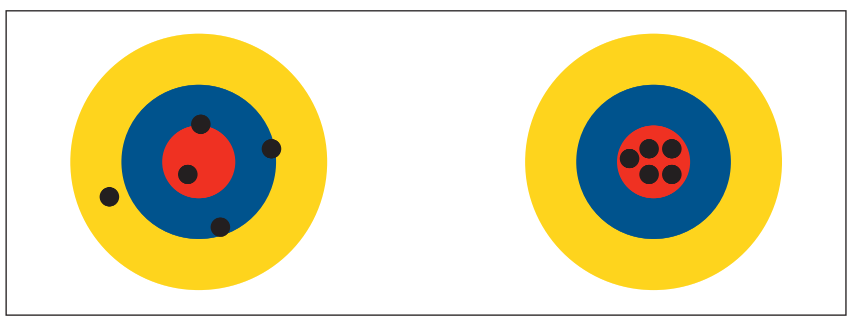
Thumb through any instrument specification and you are presented with a whole host of technical terms describing the product's capability. There are some basic ones which are often misunderstood, though — **accuracy**, **precision**, **resolution** and **sensitivity** spring to mind.

Basic Terminology

Experience has shown that some basic metrological terms are often confused. What is the difference between **accurate** and **precise**, **resolution** and **sensitivity**, **instability** and **noise**? We'll use some graphics to illustrate. Firstly, there are some archery or shooting targets. Four marksmen were aiming for the center "bulls-eye". This is analogous to making a perfect measurement with the "bull" being the conventional, "true value". So, take aim and fire five rounds...

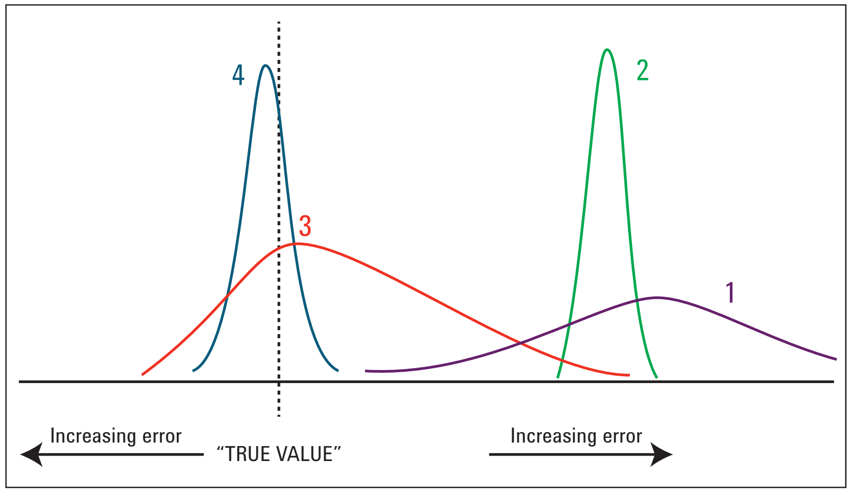


Looking at the first target (above left), the shots are widely distributed and mostly off-target — this guy's obviously a beginner, both inaccurate and unrepeatable. However, is the second marksman (above right) much better? These shots are closely grouped but they've all missed the target completely! He's precise but inaccurate. On to the third (below left) and our man has reliably hit the target but the shots are dispersed — so we have accuracy (two in the "bull") but imprecision. Of course, the final target shows the way it should be done — an Olympic champion's performance perhaps — little deviation from "true" every time, showing both accuracy and precision.



As far as calibration is concerned, the attribute **accurate** often also implies **precise** but it's worth remembering it may not be the case. Conversely, the supplier that claims his product is **precise** may not be making any claim at all for its correctness (relationship to national standards) — be warned!

The degree of accuracy and precision results from the combined effect of measuring equipment, technique, environmental conditions and the characteristics of the item being tested. If a series of repeated measurements were made and the data plotted as a histogram (bar graph), the shape described by the bar-heights represents the distribution.

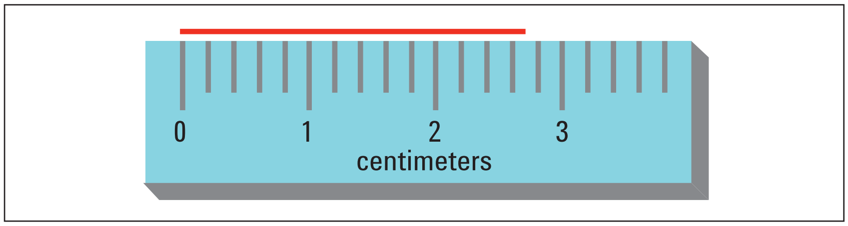


The plots show the performance of our marksmen when given machine guns (lots of data), where their aiming-point (bulls-eye) is the "true value". The distance of each peak from "true" is their average error and the width of the curve shows the dispersion. Whose performance is represented by each plot, do you think?

1. *The "beginner" is purple (inaccurate/imprecise)*
2. *The second marksman is green (repeatable but poor accuracy)*
3. *Red is the intermediate marksman (accuracy but not good precision)*
4. *The "expert" is blue (accurate and precise)*

Since they all had the same number of shots, the area under the curve must be equal (the total length of the histogram bars is the same) and so the plots have different "amplitudes". The curve shape depends upon each individual's performance and the amount of data analyzed, but we've assumed normal or Gaussian distribution. In calibration, of course, we don't know the "true value" and an uncertainty is effectively a figure of merit for the reported measurement — the limit of potential inaccuracy which should encompass the measured value's deviation from true.

Sometimes **resolution** is mistaken to be the same as accuracy. This misconception often relates to instruments with digital read-outs where a similar assumption is that, for example, a frequency counter with 11 digits must be a hundred times more accurate than one with 9 digit resolution. Resolution is just the discrimination that the instrument can show.



Look at this metric ruler; its resolution is 2 millimeters (one fifth of a centimeter) even though it can readily be used to measure the length of the red line with better estimated resolution (certainly to 1 mm and possibly 0.1 mm with magnification). However, our ability to visually subdivide between the marked graduations contributes to the uncertainty of the measurement. From inspection the evidence is that the line is between 2.6 and 2.8 cm and, considering only the resolution, it would be reported as 2.6 ± 0.2 cm. If some form of magnification were available, the measured value might be stated as 2.65 ± 0.05 cm.

But what of **sensitivity** and resolution? Whereas resolution is a measure of the smallest change in output (indication) that is possible, sensitivity relates to the smallest change in the input (stimulus) that causes a discernible change in the output. So there is an association between these two terms.

Likewise, **instability** and **noise** are both qualifications of change over time but might be best differentiated by considering "stability" to be most commonly used over periods of a second or more and "noise" for shorter intervals. Stability is sometimes also interchanged with **drift** and, in relation to quartz oscillator specification, the specialized term **ageing rate**.

Specifications, Characteristics, Features, Attributes and Supplemental data

The above terms can all describe your instrument's capability. Agilent Technologies has guidance for how its products' performance is defined. Check the **Specification Guideline** for more information.

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