The Goal Posts, the Wind, and the Coin Flip: A Practical Guide to Measurement Decision Risk

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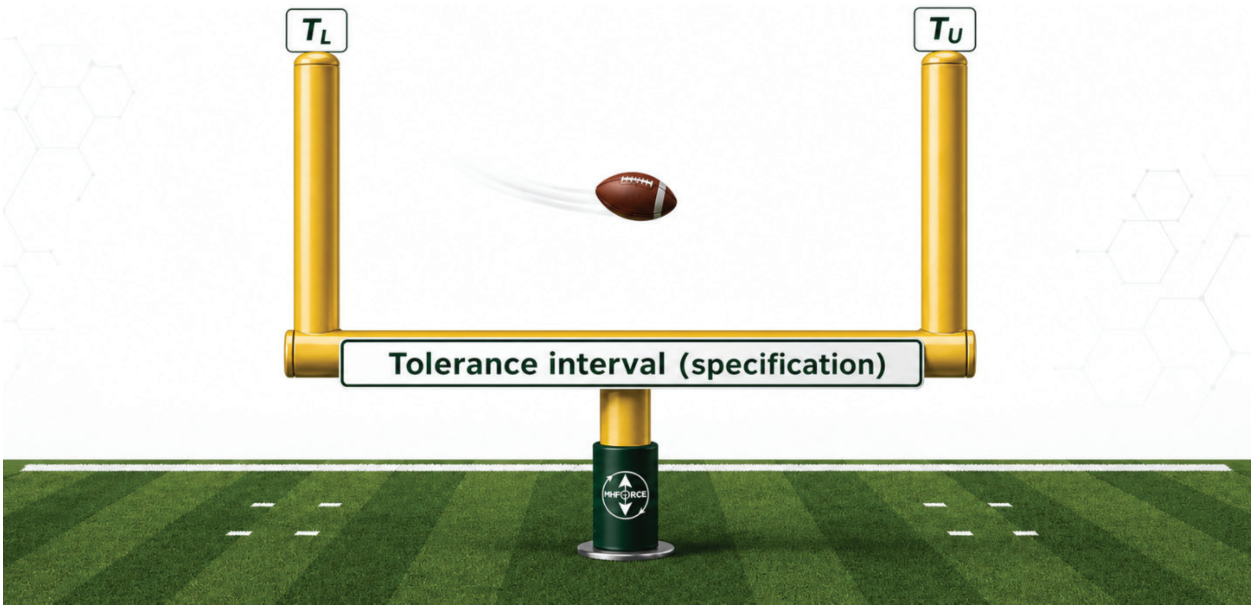

Figure 1. The two uprights are your tolerance limits, T_L and T_U. The ball must pass through the window. Conformity works the same way (JCGM 106:2012 Section 5).

Every time a calibration laboratory issues a pass or fail statement, it is making a bet. The question is whether it knows the odds. Most do not, and neither do the customers who receive the certificate.

There is a moment in every close football game that captures this problem perfectly. The kicker lines up for a field goal. The ball is snapped. He kicks. It sails toward the goal posts, and for one agonizing second, nobody knows. Was it good? Everything about measurement decision risk lives in that moment.

The Goal Posts Are Your Specification Limits

In American football, the two vertical uprights define a window. The ball either passes through or it does not. The uprights do not care about the wind, the kicker's technique, or whether he made the last ten from this distance. They are fixed.

In metrology, we call that window the tolerance interval. The left upright is the lower tolerance limit T_L. The right upright is the upper tolerance limit T_U. A measurement result that lands between them is conforming. One that lands outside is not. This is defined in JCGM 106:2012 Section 5. There are only two outcomes (binary): it's in, or it's not.

Specific Risk: This Kick, Right Now

The kicker kicks the ball. It travels toward the uprights. There is one question: Did this particular ball clear these particular posts? That is specific risk. It is the probability of an incorrect conformity decision for this single measurement result, evaluated at the

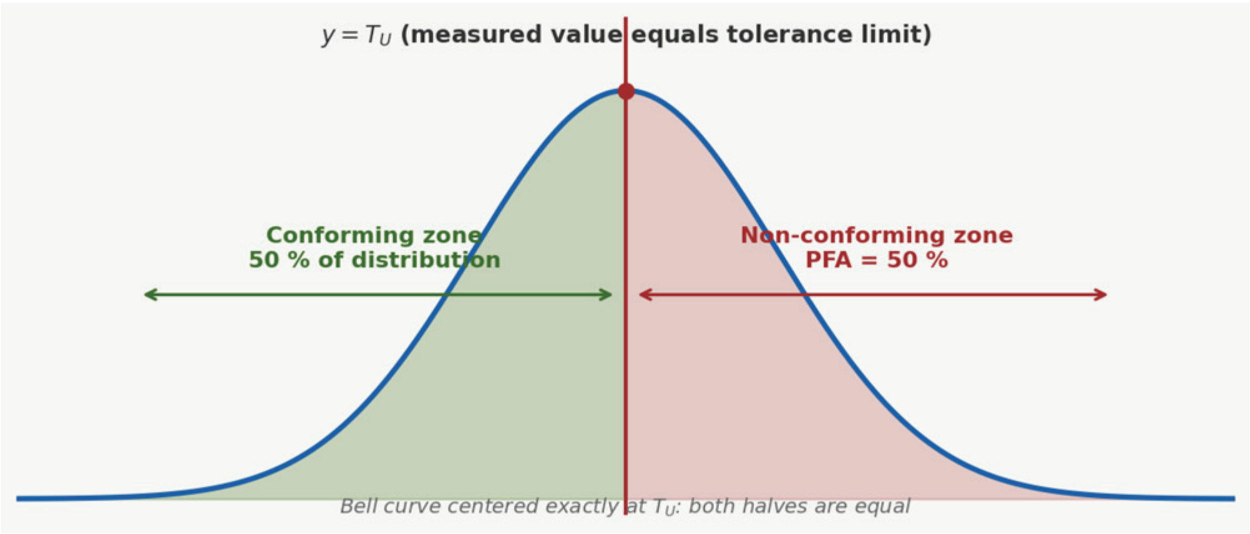

Figure 2. When $y = T_U$, the Gaussian distribution is centered exactly at the tolerance limit. Both halves are equal: conforming zone = 50 %, non-conforming zone = 50 %, PFA = 50 % (JCGM 106:2012 Section 8.3.1.2).

JCGM 106:2012 Section 8.3.1.2 states this directly: with a simple acceptance decision rule and a symmetric unimodal distribution, the probability of accepting a non-conforming item can be as large as 50 % when the measured value lies close to the tolerance limit. UKAS LAB 48, Edition 5, Appendix D, demonstrates this numerically.

exact point where the measured value lies relative to the tolerance boundary. JCGM 106:2012 Section 9.3.2 defines this as the *specific consumer's risk*.

When a measured value lands exactly at the tolerance limit, the uncertainty distribution sits with exactly half its area inside the specification and half outside. The probability that the true value is non-conforming is 50 %. You accepted the item. You had the same odds as a coin flip.

Specifying a Test Uncertainty Ratio (TUR) or Measurement Capability Index C_m on a purchase order does not change this. A TUR of 4:1 is a population-level control. At any single measurement point near the tolerance boundary, the conditional PFA under simple acceptance is still governed by where the measured value lands, not by the TUR requirement in the purchase order.

Global Risk: The Season Record from the 35-Yard Line

Now we change the question entirely. Instead of asking about this one kick, we step back and ask: how often does our kicker succeed from the 35-yard line across an entire season? He makes 97 % of them. Global risk takes that population view.

In metrology, global consumer risk asks: across the entire population of measurements, we perform on items like these, how often do we falsely accept a non-conforming item? This is the framework behind ANSI/NCSL Z540.3 and the common industry target of keeping global PFA below 2 %. But here is the catch: the global average tells you about the population. It tells you nothing about the individual conformity decision in front of you right now.

The Wind: Measurement Uncertainty and the Acceptance Limit

Measurement uncertainty is the wind. The tolerance limits are fixed by the customer or the standard. But because every measurement carries uncertainty, a result that lands at the tolerance limit cannot be trusted to represent a conforming item. So we move the acceptance limit inward from the tolerance limit by a guard band, exactly as the kicker adjusts his aim away from the upright to compensate for the drift the wind will introduce.

JCGM 106:2012 Section 8.1.2 makes this precise. An acceptance interval of permissible measured values is defined by one or two acceptance limits. These acceptance limits can be chosen to balance

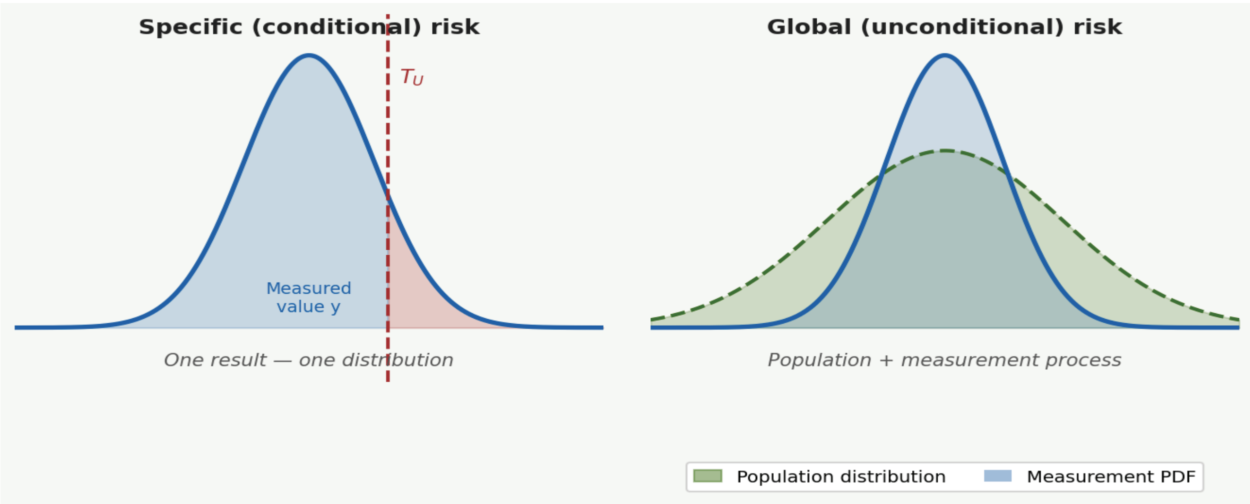

Figure 3. Specific risk (left) uses one distribution centered on the single measurement result. Global risk (right) integrates a joint distribution combining population spread with measurement uncertainty (JCGM 106:2012 Sections 9.4 and 9.5).

An instrument passing a global PFA criterion of 2 % may have a specific risk for false acceptance approaching 50 % on individual measurements near the tolerance boundary. The global number is an average. It masks what is happening at the edges. Both frameworks are legitimate, yet they answer fundamentally different questions and must not be confused.

the risks associated with accepting non-conforming items (consumer's risk) or rejecting conforming items (producer's risk). The key statement from JCGM 106:2012 is that these acceptance limits are business or policy decisions that depend on the consequences associated with deviations from intended product quality.

JCGM 106:2012 Section 8.3.1 describes this guard band formally. When a measured value lies close to a tolerance limit, the probability of an incorrect accept or reject decision can be as large as 50 % under simple acceptance. A guard band reduces this risk by setting an acceptance limit offset from the tolerance limit. The length parameter, w, of the guard band is the interval between the tolerance limit and the acceptance limit. For guarded acceptance, w is positive: the acceptance limit moves inward.

JCGM 106:2012 Section 9.5.6 provides the most compelling argument for reducing measurement uncertainty. It shows that for a simple acceptance rule ($w = 0$), improving the Measurement Capability Index C_m from 2 to 10 reduces both consumer risk and producer risk simultaneously. The specification did not change. Only the measurement capability changed. This is why investment in measurement capability is not merely a technical preference. It is a cost management decision.

The guard band width required to achieve a desired PFA level is directly proportional to the standard uncertainty u. For a specific risk approach limiting PFA to 2.5 % at the acceptance limit, the guard band is $w = 1.96 \times u$, derived from the inverse of the standard normal distribution (NORM.S.INV(0.975) = 1.96). A laboratory with standard uncertainty $u = 0.30$ requires a guard band of only 0.59. A laboratory with $u = 1.00$ requires a guard band of 1.96 for the same risk target. The kicker facing heavy wind must aim much farther inside the post than the kicker in calm air.

The Guard Band in Detail

The figure below shows the guard band geometry directly. For each scenario, the full tolerance interval runs from T_L to T_U (the goal posts). The acceptance limit A_U sits inside T_U by the guard band w. Results within A_U to T_L are accepted. Results between A_U and T_U fall in the guard band zone. Results beyond T_U are non-conforming regardless.

Under low uncertainty, the guard band is narrow, and most of the tolerance interval remains usable for acceptance. Under high uncertainty, the guard band consumes a substantial portion of the tolerance, leaving a much narrower acceptance zone. The PFA at

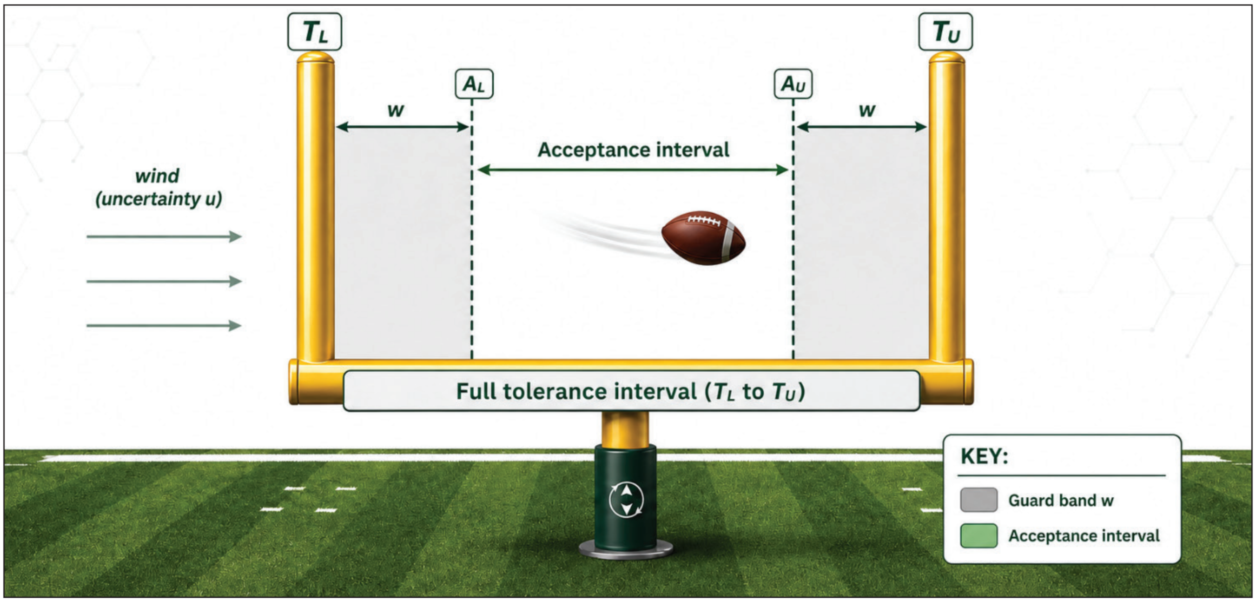

Figure 4. The wind analogy is made explicit. Left: low uncertainty (C_m = 6.25), small guard band *w*, acceptance limit close to tolerance limit, small PFA. Right: high uncertainty (C_m = 2.5), wide guard band, kicker must aim well inside the post to achieve the same PFA. The goal posts (tolerance limits) have not moved. Only the measurement capability changed (JCGM 106:2012 Sections 8.3, 9.5.6).

the acceptance limit A_U is held to 2.5 % in both cases because the guard band is sized proportionally to the standard uncertainty.

Three Scenarios: Where the Ball Lands Determines the Risk

The three panels in Figure 6 show the same tolerance interval and the same measurement uncertainty. Only the position of the measured value y changes. This is the most important diagram in this article, and it is frequently drawn incorrectly.

When y is well inside the specification, the bell curve is far from T_U, and the red tail beyond T_U is negligible. PFA approaches zero. When y equals the guard-banded acceptance limit A_U, exactly 2.5 % of the bell curve's area extends beyond T_U. This is the boundary of acceptance under a specific risk decision rule. When y equals T_U itself with no guard band applied, the bell curve is centered exactly at the tolerance limit and the distribution splits precisely 50/50. This is the coin-flip outcome that JCGM 106:2012 Section 8.3.1.2 warns about.

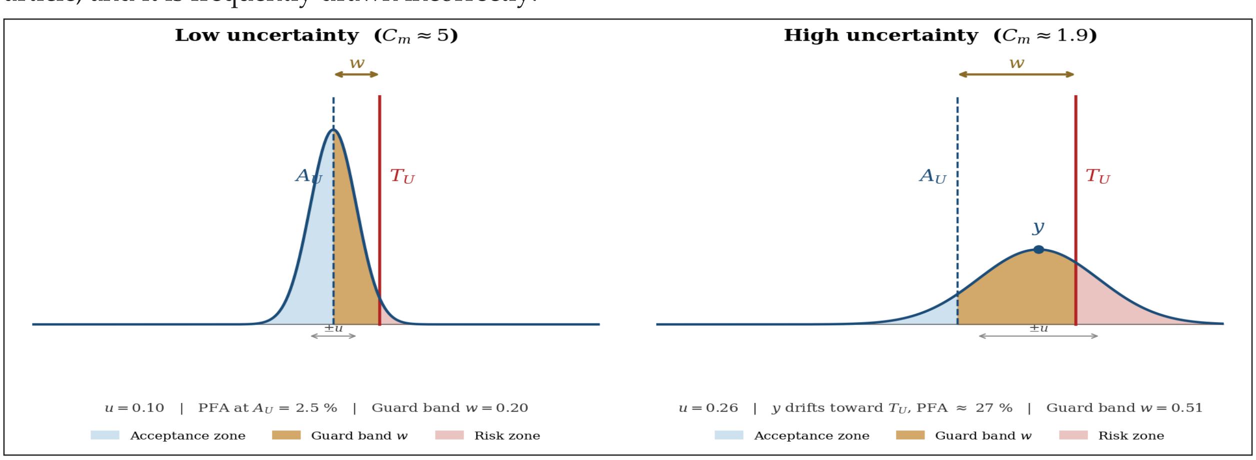

Figure 5. Guard Band Geometry. Left: low uncertainty, small *w*. Right: high uncertainty, wide *w*. In both cases PFA at A_U = 2.5 %. The acceptance zone (blue) shrinks as uncertainty grows (JCGM 106:2012 Section 8.3.2).

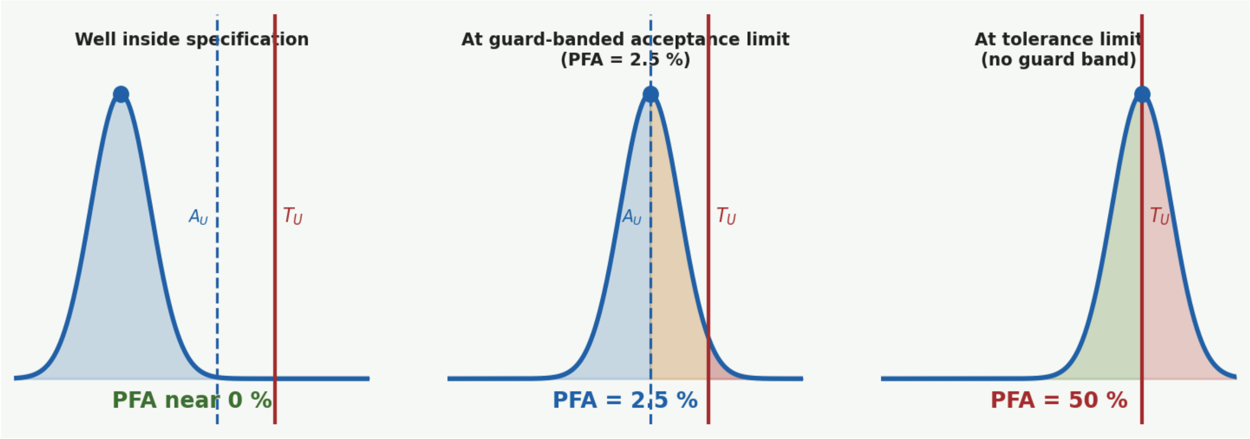

Figure 6. Three measured values, same tolerance interval, same measurement uncertainty. Left: PFA near 0 %. Center: measured value at acceptance limit A_U, PFA = 2.5 % (only a small red tail extends beyond T_U). Right: measured value at tolerance limit with no guard band, PFA = 50 % with equal green and red areas (JCGM 106:2012 Sections 8.2 and 8.3. Decision Rules & Statements of Conformity V1.42, Section 3).

Three Practical Lessons

The goal posts are fixed, yet your aim is not

The customer's specification is not yours to change. But the acceptance limit is yours to set in agreement with the customer. Set it without accounting for uncertainty, and you may be calling kicks good that actually hit the upright and do not go in.

Every kick is its own decision

Specific risk is the honest answer to the question your customer actually cares about: was this particular instrument, at this measurement point, genuinely conforming? Global risk tells you how your program performs on average. Both matter. Neither replaces the other.

The customer sets the rules, not the kicker

What counts as an acceptable level of risk is defined by the customer's business needs and the consequences of false acceptance. JCGM 106:2012 states in its introduction that choosing acceptance limits is a business or policy decision. ISO/IEC 17025:2017 Clause 7.1.3 makes the agreement with the customer a contractual requirement.

References and Further Reading

- **JCGM 106:2012:** Evaluation of measurement data: the role of measurement uncertainty in conformity assessment. Sections 8.1, 8.2, 8.3.1.2, 9.3, 9.5.3, 9.5.6. The mathematical foundation for this article.
- **UKAS LAB 48, Edition 5 (July 2024):** Decision rules and statements of conformity. Appendix D demonstrates why simple acceptance without an uncertainty precondition is problematic. Freely available at ukas.com.
- **ILAC-G8:09/2019:** Guidelines on decision rules and statements of conformity.
- **ISO/IEC 17025:2017:** General requirements for the competence of testing and calibration laboratories. Clauses 3.7, 7.1.3, 7.8.6.1, and 7.8.6.2.
- **Decision Rules and Statements of Conformity V1.42 (Zumbrun, Cenker, Shah, 2026):** Highly recommended. Practitioner-level guidance with full worked examples for specific risk, global risk, guard band calculations, and the resistor production cost example. Available at https://mhforce.com/wp-content/uploads/2026/03/Decision-Rule-Guidance-V-1.41-3.pdf
- **ANSI/NCSL Z540.3 Handbook:** Covers the 2 % global PFA requirement and practical implementation methods.
- **Dobbert, M. (2008):** A Guard-Band Strategy for Managing False-Accept Risk. NCSL Workshop and Symposium. Source for Method 6 managed guard bands.
- **ASME B89.7.4.1-2005:** Measurement Uncertainty and Conformance Testing: Risk Analysis.

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