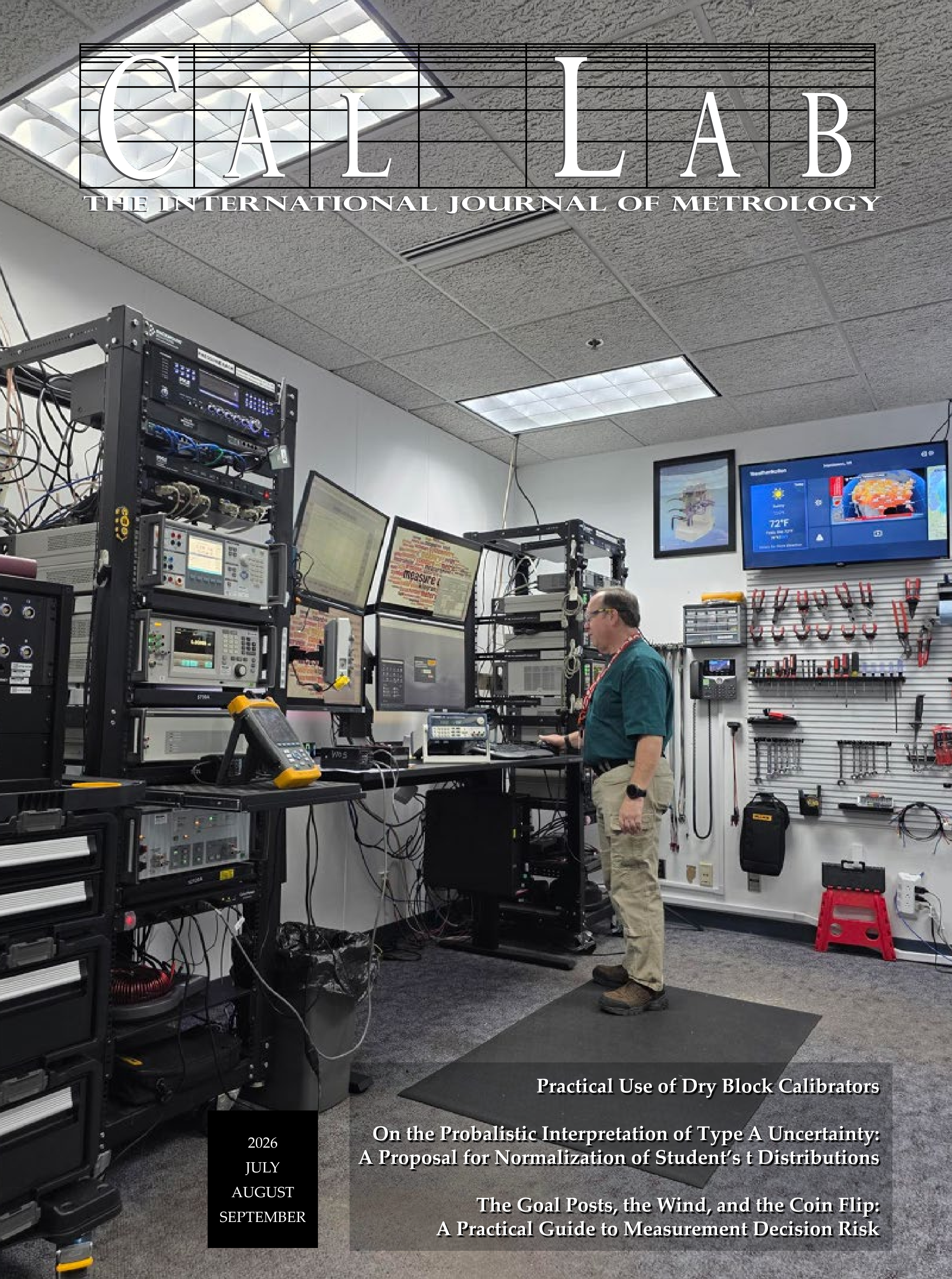
CAL LAB

THE INTERNATIONAL JOURNAL OF METROLOGY



2026
JULY
AUGUST
SEPTEMBER

Practical Use of Dry Block Calibrators

On the Probalistic Interpretation of Type A Uncertainty: A Proposal for Normalization of Student's t Distributions

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

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VOLUME 33, NUMBER 3

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FEATURES

DEPARTMENTS

ON THE COVER: Metrologist Harry Cole performing a calibration of a Fluke 8846A at the Next Era Energy Point Beach calibration laboratory.

CALENDAR

UPCOMING CONFERENCES & MEETINGS

The following event dates are subject to change. Visit the event URL provided for the latest information.

Sep 6-11, 2026 CPEM. Madrid, Spain. Conference on Precision Electromagnetic Measurements. Hosted by the Centro Español de Metrología (CEM), the conference will cover the frequency range from direct current (DC) to the optical region and will concern applications related to electromagnetic measurements. https://cpem2026.com/

Sep 16-18, 2026 IMEKO TC4 Conference with Special TC11 Technical Session. Prague, Czech. The conference will bring together researchers, metrologists, and industry professionals to discuss the latest advances in electrical, electronic, and magnetic measurement techniques, instrumentation, standards, as well as testing, inspection, and certification. https://imeko2026.fel.cvut.cz/

Sep 17-18, 2026 IMEKO TC17 ISMCR. Rio de Janeiro, Brazil. The 27th International Symposium on Measurement and Control in Robotics is an IMEKO TC17 Event and will explore advances in measurement, sensing and intelligent systems for robotics, with emphasis on autonomous systems and human–robot interaction. https://ismcr.org/2026-ismcr/

Sep 28-29, 2026 IMEKO TC10 Conference. Lisbon, Portugal. The International Measurement Confederation (IMEKO), through its Technical Committee 10 (TC10) on Measurement for Diagnostics, Optimization and Control, invites researchers, scientists, and practitioners from academia and industry worldwide. https://www.imekotc10-2026.sztaki.hu/

Oct 4-9, 2026 EuMW. London, UK. European Microwave Week. The European Microwave Conference (EuMC), The European Microwave Integrated Circuits Conference (EuMIC), and The European Radar Conference (EuRAD). https://www.eumw.eu/conferences/

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EDITOR'S DESK

Commentary on Community and DOIs

There are a lot of different types of journal publications out there. I think this one in particular marks squarely in the box as "trade journal." Okay, so what is that? Let me explain by what we do: inter-laboratory comparisons, "How-To" articles, industry and research news, industry events, new trends and practices, etc.

Though you will find articles written by scientists and engineers that explore theories and poke holes in current practice, we are not a scholarly or scientific journal. We do not register Digital Object Identifiers (DOIs) or include ORCIDs for author contributors and have no plans to do such. If CAL LAB could talk, it would talk about community—the measurement community.

When we reach out to the wider community for material, or when those in the wider community reach out to us, we've already been introduced in a sense. We know the hierarchy, industry standards, and challenges of recruitment—general knowledge of any established trade—but there also exists a culture of knowing the secret password (uncertainties) or keeping a personal collection of thermometers, multimeters, or other basic measurement tool. In fact, you know a colleague or are THAT colleague with a storage unit, attic, or house devoted to a collection of instrumentation.

So, think about this publication as your publication. I'm hoping it speaks to you somehow as a resource that connects you to a wider measurement community.

The articles in this issue cover a lot of ground from hands-on, to measurement theory, to industry standards. Starting with this issue's Metrology 101. I know a lot of readers work in the field of temperature, so we were super pleased to get a paper on "Practical Use of Dry Block Calibrators" by David Southworth of Isotech in England.

Next, Manuel Rodríguez Higuero of INTA, Spain, continues the discussion on Type A uncertainty contributions as presented in the GUM and Supplement 1, "On the Probabilistic Interpretation of Type A Uncertainty: A Proposal for Normalization of Student's t Distributions." Readers familiar with this subject will recall Hening Huang's articles from past years. Previous articles and papers can be easily found on callabmag.com by doing a search by keyword or author name. As this paper is one of our more advanced contributions, as a reminder, author information is included at the end of each article if readers have any questions.

Finally, we have a paper by Henry Zumbrun of Morehouse Instrument Company in York, Pennsylvania, on "The Goal Posts, the Wind, and the Coin Flip: A Practical Guide to Measurement Decision Risk." His paper presentations are one of the more popular ones at NCSLI each year, so we appreciate his yearly contribution to our lineup of articles.

Besides the annual Workshop & Symposium, NCSLI also has section and region meetings that welcome new faces. For upcoming meetings, visit: https://ncsli.org/page/UCSM.

Happy Measuring,

Sita Schwartz

CALENDAR

Oct 5-9, 2026 International Symposium on Standards, Applications and Quality Assurance in Medical Radiation Dosimetry (IDOS). Vienna, Austria. The Symposium will provide an international forum to discuss and disseminate the latest advances in radiation dosimetry for medical application of ionizing radiation, radiation protection and associated standards. https://www.iaea.org/events/idos-2026

Oct 14-16, 2026 IMEKO TC26 MetroArchaeo. Bari, Italy. Metrology for Archaeology and Cultural Heritage (MetroArchaeo) brings together researchers and operators in the enhancement, characterization and preservation of archaeological and cultural heritage with the main objective of discussing production, interpretation and reliability of measurements and data. https://www.metroarcheo.com/

Oct 19-23, 2026 EURAMET Autumn School on Environmental Sensors and Sensor Networks. METAS, Bern, Switzerland. This five-day autumn school aims to provide the participants with the knowledge and tools needed to tackle the challenges associated to sensors and sensor networks through metrology. https://www.euramet.org/european-metrology-networks/pollution-monitoring/news-events

Oct 26-28, 2026 NCSLI Technical Exchange. Albuquerque, NM. Get ready for four dynamic days where the calibration, test & measurement, and metrology community comes together in Albuquerque. https://ncsli.org/mpage/TE2026

Oct 27-29, 2026 IMEKO TC7, TC11, TC13, T21 AMCTM. Faro, Portugal. Advanced Mathematical and Computational Tools in Metrology. The overall aim of the conference is to provide a multi-disciplinary forum to address how the metrology community can support trustworthy workflows across all scientific and technical disciplines. https://amctm26.com/

Nov 15-21, 2026 42nd Asia Pacific Metrology Program General Assembly and Related Activities. Wellington, New Zealand. Hosted annually within the Asia-Pacific region, APMP is the premier forum advancing metrological science, capability, and collaboration among national metrology institutes (NMIs), with particular emphasis on strengthening developing economies. https://www.apmp2026.nz/

Find more events online:
www.callabmag.com/calendar/

SEMINARS & WEBINARS: Dimensional

Sep 28-29, 2026 Gage Calibration Methods Class. Mason, OH. QC Training. This hands-on workshop offers specialized training in gage calibration and repair for the individual who has some knowledge of basic Metrology. https://qctraininginc.com/courses

Sep 30, 2026 EDU-101: Introduction to Dimensional Metrology Hand Tools I – Fundamental Tools. City of Industry, CA. Mitutoyo. EDU-101 is a one-day class for entry-level team members who need to learn the fundamentals of the steel rule, caliper, micrometer, pin gage, and gage block. https://www.mitutoyo.com/training-education/

Sep 30-Oct 1, 2026 EDU-113: Dimensional Gage Calibration. Aurora, IL. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://mitutoyo.com/training-education/classroom/

Oct 5, 2026 Virtual ISO "Hands-On" Gage Calibration & Repair. IICT. This 1-day online precision gage and repair training offers specialized training in calibration and repair for individuals with some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Oct 7, 2026 Virtual ISO "Hands-On" Gage Calibration & Repair. IICT. This 1-day online precision gage and repair training offers specialized training in calibration and repair for individuals with some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Oct 13-14, 2026 ISO Hands-On Gage Calibration & Repair. Omaha, NE. This 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/calibration-metrology-training-events/

Oct 15-16, 2026 ISO Hands-On Gage Calibration & Repair. Sioux, SD. This 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Oct 27-28, 2026 EDU-113: Dimensional Gage Calibration. Houston, TX. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://mitutoyo.com/training-education/

Nov 3-4, 2026 EDU-104: Intro to Dimensional Metrology Hand Tools IV. Aurora, IL. Mitutoyo. EDU-104 is a two-day class for entry-level team members who need to learn the fundamentals of the steel rule, caliper, micrometer, pin gage, gage block, surface plate, height gage, indicator and stands, angle block, v-block, and sine bar. https://mitutoyo.com/training-education/classroom/

Nov 5-6, 2026 EDU-302: Small Tool Repair Course. Aurora, IL. Mitutoyo. This hands-on and interactive session is designed to support technicians who are responsible for the regular maintenance, repair, and calibration of common precision measuring gages. https://mitutoyo.com/training-education/classroom/

Nov 9-10, 2026 ISO Hands-On Gage Calibration & Repair. Bloomington, MN. IICT. This 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. The workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Nov 10-11, 2026 Gage Calibration Methods Class. Mason, OH. QC Training. This hands-on workshop offers specialized training in gage calibration and repair for the individual who has some knowledge of basic Metrology. https://qctraininginc.com/courses

Nov 12-13, 2026 Virtual ISO Hands-On Gage Calibration & Repair. IICT. This 2-day online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. The workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc https://calibrationtraining.com/calibration-metrology-training-events/

Nov 17, 2026 1-Day Virtual ISO Hands-On Gage Calibration & Repair. Online from IICT. This online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Nov 17-18, 2026 EDU-113: Dimensional Gage Calibration. Lakeland, FL. Mitutoyo America's Gage Calibration course is a unique, active, educational experience designed specifically for those who plan and perform calibrations of dimensional measuring tools, gages, and instruments. https://mitutoyo.com/training-education/classroom/

Nov 18-19, 2026 Dimensional Measurement. Port Melbourne VIC, Australia. NMI. This 2-day course presents a comprehensive overview of the fundamental principles in dimensional metrology and geometric dimensioning and tolerancing. https://shop.measurement.gov.au/

Nov 19, 2026 1-Day Virtual ISO Hands-On Gage Calibration & Repair. Online from IICT. This online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Dec 10-11, 2026 2-Day Virtual ISO Hands-On Gage Calibration & Repair. Online from IICT. This 2-day online precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

Dec 17-18, 2026 ISO Hands-On Gage Calibration & Repair. Bloomington, MN. This 2-day precision gage and repair training offers specialized training in calibration and repair for the individual who has some knowledge of basic Metrology. Approximately 75% of the workshop involves "Hands-on" calibration, repair, and adjustments of micrometers, calipers, indicators, height gages, etc. https://calibrationtraining.com/

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SEMINARS & WEBINARS: Electrical

Oct 27-28, 2026 Electrical Measurement. Lindfield NSW, Australia. NMI. This course provides in-depth knowledge of the theory and practice of electrical measurement using digital multimeters and calibrators; special attention is given to important practical issues such as grounding, interference and thermal effects. https://shop.measurement.gov.au/

Oct 29, 2026 High-Voltage Test and Measurement. Lindfield NSW, Australia. NMI. This one-day workshop provides hands-on experience and practical techniques involved in performing high-voltage tests and measurements, and explains how to make such tests and measurements in accordance to relevant international and Australian standards. https://shop.measurement.gov.au/

Nov-12, 2026 MET-101 Basic Hands-On Metrology Course. Everett, WA. Fluke Calibration. This Metrology 101 basic metrology training course introduces the student to basic measurement concepts, basic electronics related to measurement instruments and math used in calibration. https://www.fluke.com/

SEMINARS & WEBINARS: Flow

Oct 5-8, 2026 Gas Flow Calibration. Web Classroom. Fluke Calibration. This is a four day training course in the operation and maintenance of a Fluke Calibration molbloc/molbox system. https://www.fluke.com/

SEMINARS & WEBINARS: General

Sep 29, 2026 EDU-510: Calibration Laboratory Essentials: From Setup to Quality Management. Mitutoyo. Lakeland, FL. This practical one-day program is designed for professionals involved in establishing, managing, or improving calibration laboratories. It provides guidance on building a technically competent, quality-focused lab aligned with international best practices and ISO/IEC 17025 requirements. https://mitutoyo.com/

Oct 5-7, 2026 C-101 Calibration. Gonzales, LA. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. https://trinova.arlo.co/

Oct 26-28, 2026 C-101 Calibration. Memphis, TN. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. https://trinova.arlo.co/

Nov 2-4, 2026 C-101 Calibration. Mobile, AL. TriNova Technical Education. This instructor led calibration course is delivered by our experienced technical education specialists who deliver a high-quality course covering calibration fundamentals, detailed documentation procedures, temperature, and pressure basics, and basics of DP flow calibration. https://trinova.arlo.co/

SEMINARS & WEBINARS: Industry Standards

Sep 28-29, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Boulder, CO. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/

Sep 30-Oct 1, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Boulder, CO. A2LAWPT. This ISO/IEC 17025 internal auditor training course introduces participants to ISO 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. https://a2lawpt.org/

Oct 6-7, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs. IAS. This 2-day, online training Course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/

Oct 13-15, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual Event. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/

Oct 20-22, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual Event. A2LAWPT. This ISO/IEC 17025 internal auditor training course introduces participants to ISO 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. https://a2lawpt.org/

Oct 27-28, 2026 Understanding the Requirements and Concepts of ISO/IEC 17025:2017. ANAB Live online course. Understand requirements of ISO/IEC 17025:2017, including general, structural, resource, process, and management system requirements. https://anab.ansi.org/training/

Nov 2-3, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Frederick, MD. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/events/

Nov 4-5, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Frederick, MD. A2LAWPT. This ISO/IEC 17025 internal auditor training course introduces participants to ISO 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. https://a2lawpt.org/

Nov 12-13, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual Event. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/

Nov 17-Nov 20, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual Event. A2LAWPT. This ISO/IEC 17025 internal auditor training course introduces participants to ISO 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. https://a2lawpt.org/events/

Nov 24-25, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs. IAS. This 2-day, online training Course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/training/

Dec 1-2, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs (Spanish Instruction for the Americas). IAS. This 2-day, online training course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/training/

Dec 1-2, 2026 3004 Understanding ISO/IEC 17025 for Testing and Calibration Labs (for Middle East, India, and South Asia). IAS. This 2-day, online training Course applies to testing and calibration laboratories and regulatory agencies seeking to specify 17025 within their policies and regulations. https://www.iasonline.org/training/

Dec 8-9, 2026 Understanding the Requirements and Concepts of ISO/IEC 17025:2017. ANAB Live online course. Understand requirements of ISO/IEC 17025:2017, including general, structural, resource, process, and management system requirements. https://anab.ansi.org/

Dec 8-9, 2026 Understanding ISO/IEC 17025:2017 for Testing & Calibration Labs. Virtual Event. A2LAWPT. This course is a comprehensive review of the philosophies and requirements of ISO/IEC 17025:2017. https://a2lawpt.org/

Dec 15-16, 2026 Auditing Your Laboratory to ISO/IEC 17025:2017. Virtual Event. A2LAWPT. This ISO/IEC 17025 internal auditor training course introduces participants to ISO 19011, the guideline for auditing management systems as applied to ISO/IEC 17025:2017. https://a2lawpt.org/

SEMINARS & WEBINARS: Mass

Oct 19-30, 2026 Mass Metrology Seminar. Gaithersburg, MD. NIST. The NIST Office of Weights and Measures (OWM) Mass Metrology seminar is a 2-week, "hands-on" course. It incorporates lectures, demonstrations and laboratory work in which the participant performs measurements by applying procedures and equations discussed in the classroom. https://www.nist.gov/

SEMINARS & WEBINARS: Measurement Uncertainty

Oct 1-2, 2026 Measurement Uncertainty Budgets. Greer, SC. QC Training. This workshop presents a combination of lecture and classroom exercises to demonstrate the principles of measurement uncertainty analysis. https://qctraininginc.com/courses

Oct 7 & 9, 2026 Introduction to Estimating Measurement Uncertainty. Online Delivery. Australian NMI. This 2-day course will give you a clear step-by-step approach to uncertainty estimation with practical examples; you will learn techniques covering the whole process from identifying the sources of uncertainty in your measurements right through to completing the uncertainty budget. https://shop.measurement.gov.au/collections/physical-metrology-training

Oct 12-13, 2026 3006 Uncertainty of Measurement for Labs. IAS. Online training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/

Oct 20, 2026 Estimating Measurement Uncertainty for Physical Metrologists. Port Melbourne VIC. Australian NMI. The course provides a clear, systematic method for understanding and applying uncertainty estimation techniques in physical metrology with focus on real-world measurement and calibration examples. https://shop.measurement.gov.au/

Oct 27-29, 2026 EDU-210: Measurement Uncertainty and Decision Rules. Lakeland, FL. Over 95% of uncertainty budgets are done using basic math and a simple spreadsheet. This course focuses on the fundamentals and skips the more complicated math that scares away most people, and in practice, is hardly used. https://mitutoyo.com/

Nov 3, 2026 Introduction to Measurement Uncertainty. Frederick, MD. A2LAWPT. This introductory course provides calibration and testing laboratory professionals with a practical foundation in measurement uncertainty evaluation. https://a2lawpt.org/events/

Dec 2-3, 2026 3006 Uncertainty of Measurement for Labs (for the Middle East, India, and South Asia). IAS. Online training includes case studies and discussions, with application of statistical components in practical examples that are frequently encountered by testing laboratories. https://www.iasonline.org/training/

Dec 10-11, 2026 Introduction to Measurement Uncertainty. Virtual Event. A2LAWPT. This introductory course provides calibration and testing laboratory professionals with a practical foundation in measurement uncertainty evaluation. https://a2lawpt.org/events/

SEMINARS & WEBINARS: Pressure

Oct 14-15, 2026 Pressure Measurement. Port Melbourne, VIC. Australian NMI. This two-day course covers essential knowledge of the calibration and use of a wide range of pressure measuring instruments, their principles of operation and potential sources of error — it incorporates extensive hands-on practical exercises. https://shop.measurement.gov.au/collections/physical-metrology-training

Nov 16-20, 2026 TWB-1061 Principles of Pressure. Web-based Classroom. This is a short form of the regular five-day in-person Principles of Pressure Calibration class. https://www.fluke.com/

SEMINARS & WEBINARS: Software

Oct 5-9, 2026 MC-207 Advanced MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. A five-day procedure writing course for advanced users of MET/CAL® calibrations software. https://www.fluke.com/

Oct 19-23, 2026 MC-205 MET/TEAM® Asset Management. Everett, WA. Fluke Calibration. This five-day course presents a comprehensive overview of how to use MET/TEAM® Test Equipment and Asset Management Software in an Internet browser to develop your asset management system. https://www.fluke.com/

Nov 10-13, 2026 VNA Tools Software Training. Bern-Wabern, Switzerland. METAS. VNA Tools is a free software developed by METAS for measurements with the Vector Network Analyzer (VNA). The software facilitates the tasks of evaluating measurement uncertainty in compliance with the ISO-GUM and justifying metrological traceability. The 3 day course provides a practical and hands-on lesson with this superior and versatile software. https://www.metas.ch/metas/en/home/dl/kurs_uebersicht.html

Nov 16-20, 2026 MC-206 Basic MET/CAL® Procedure Writing. Everett, WA. Fluke Calibration. In this five-day Basic MET/CAL® Procedure Writing course, you will learn to configure MET/CAL® software to create, edit, and maintain calibration solutions, projects and procedures. https://www.fluke.com/

SEMINARS & WEBINARS: Temperature & Humidity

Nov 11-13, 2026 Temperature Measurement. Lindfield, NSW. Australian NMI. This three-day course covers the measurement of temperature and the calibration of temperature measuring instruments. It incorporates extensive hands-on practical exercises. https://shop.measurement.gov.au/collections/physical-metrology-training

SEMINARS & WEBINARS: Volume

Dec 7-11, 2026 2065 Volume Metrology Seminar. Gaithersburg, MD. NIST. This 5-day NIST Office of Weights and Measures (OWM) Volume Metrology seminar enables metrologists to apply fundamental measurement concepts and hands-on laboratory procedures to volume calibrations. https://www.nist.gov/pml/owm/owm-products-and-services/training-classes-and-events

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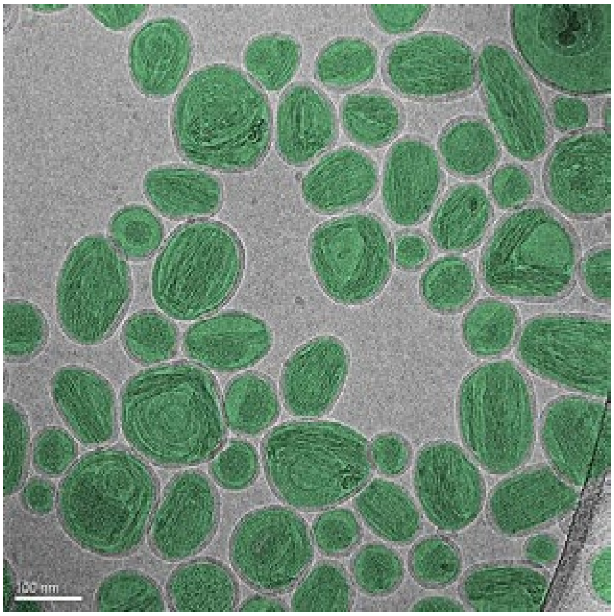
NIST Researchers Correct Common Error Confounding Nanotech Measurements

August 6, 2026 – NIST News - Nanoscience, which studies small objects, has a big problem. According to a team of scientists at the National Institute of Standards and Technology (NIST), the field confronts a pervasive error of data analysis that can give misleading insights into how these tiny objects' properties depend on their size. The team also offers a practical solution — a mathematical correction that can reveal how these materials truly behave.

Reported in ACS Nano, the team's discovery has many implications, from testing material properties to developing products that use nanotechnology, which takes advantage of the behavior of materials at very small sizes. Nanoscale objects range from a few to a few hundred nanometers across — the size range of many viruses. At the nanoscale, a material often shows properties that differ from what the same material would exhibit in larger bulk form. For example, nanoscale chunks of gold metal can appear to be ruby red in color.

Nanomaterials form the basis of a wide variety of products including electronics, ceramics, paints and plastics, and they have many applications in chemical catalysis and drug delivery. The global market for nanotech is more than $100 billion annually and growing. Making better products depends in part on measuring and analyzing how nanoscale materials perform, a part of the process that the NIST scientists say requires an update.



A colorized electron microscope image shows lipid nanoparticles containing a cancer drug. The amount of drug contained depends on the size of each nanoparticle. NIST researchers have developed a new analysis to better understand how the useful properties of nanoparticles depend on their size — in this example, to optimize drug delivery to cancer patients. The new analysis can also find use in other products that use nanoparticles and other nanomaterials, including electronics, ceramics and coatings. Credit: Dr. Pierre-Alain Burnouf/Shutterstock, Natasha Hanacek/NIST

"Many studies begin by measuring the size of a nanomaterial," said mathematical statistician Adam Pintar, a member of the NIST team. "But these measurements are imperfect, and sizing errors matter."

When researchers develop nanotechnologies like particles that glow a certain color or deliver medical treatments, their fundamental goal is to determine how the size of a nanoparticle affects its performance — such as how brightly it glows or how much medicine it carries. To do so, they plot a measure of performance versus size on a graph to analyze the trend.

However, the team noticed a common mistake in the statistical analysis of such trends. Researchers often assume that their measurements of particle size are perfectly precise and accurate. In practice, though, size measurements of nanoscale objects have limited precision and accuracy — sometimes very limited.

"These overlooked sizing errors have the effect of jostling a light bulb's dimmer switch," said electrical engineer Andrew Madison, also of the NIST team. "The errors dim the apparent relationship between the size of a particle and its brightness."

After noticing the issue in a few key publications, the team looked through several other studies that measured various nanomaterials and found similar issues.

"The dimming effect can turn out the lights for understanding the properties of a nanomaterial," said physical scientist Samuel Stavis, also of the team. "If a nanoparticle carries drugs for a medical treatment, for example, analysis of the dose could be mistaken. Or if a nanoscale wire was measured imperfectly, understanding of how much current flows through it could be off."

After identifying the broader problem, the team developed a solution by deriving and testing mathematical corrections for the apparent trends. By quantifying the limited precision and accuracy of particle size measurements, the correction reverses the dimming effect, revealing the true relationship between particle property and size.

To use the correction, researchers must estimate their measurement errors, Pintar said. The best way to do so is to obtain a reliable reference material for the particles and measure its size with their own instruments and methods. The difference between the measurement results and the reference values gives an estimate of the errors. (NIST sells a wide selection of reference materials, as do other organizations.) If there is no reference material for a particular nanomaterial, researchers can still use the mathematical correction by carefully calculating the uncertainty of their sizing measurements.

In keeping with NIST's mission to advance measurement science, the team members have identified a fundamental problem, Stavis said, and their solution will help nanoscience and nanotechnology to fulfill its potential for enhancing economic security and improving quality of life.

"It is a big ask to confront an overlooked problem at the foundation of a field of research," he said. "But other fields of research have done so, and we offer a practical solution."

A.L. Pintar, A.C. Madison, C.R. Copeland, N. Farkas and S.M. Stavis. Measurement Error Models Enable Accurate Correlation of Nanoscale Properties and Structures. ACS Nano. Published online Aug. 6, 2026. DOI: 10.1021/acsnano.5c12141

Source: https://www.nist.gov/news-events/news/2026/08/nist-researchers-correct-common-error-confounding-nanotech-measurements

Version 1.0.0 of the SI Reference Point Has Been Officially Released

BIPM News - The SI Reference Point is a digital representation of the SI Brochure, which defines the International System of Units (SI), the world's only internationally agreed system of units. By making core SI reference information available in machine-readable form, the SI Reference Point helps ensure that the SI can be used consistently in digital applications and data exchange.

Supporting Digital Metrology

The first stable release of the SI Reference Point marks an important milestone in the digital transformation of the international metrology system. It provides a common digital reference for representing SI units in machine-readable form.

The SI Reference Point provides a machine-actionable representation of the SI units that can be accessed and reused across digital environments. This helps support:

- the interoperability and reuse of measurement information;
- digital metrological traceability;
- the harmonization of digital calibration certificates and digital reference material certificates;
- consistent communication between measurement devices and sensor networks.

The SI Reference Point was developed by an international group of experts working through the CIPM Forum on Metrology and Digitalization (FORUM-MD) and its associated working groups.

Access the SI Reference Point

Version 1.0.0 of the SI Reference Point is available through the following web services: https://si-digital-framework.org/SI

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Practical Use of Dry Block Calibrators

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Isothermal Technology Ltd. (Isotech)

A dry block can give a temperature reading that looks more certain than it is. The difference between a casual measurement and a defensible one lies in understanding the measurement zone, the way heat moves through the probe, and the evidence behind the stated uncertainty.

Introduction

A block calibrator display reads 200.00°C. A calibrated reference thermometer, positioned at the specified depth within the defined measurement zone, reads 199.84°C. Neither indication is necessarily wrong. The display reports the temperature seen by the internal control sensor, whereas the reference thermometer reports the temperature realized at its specified position in the block. Any difference between that position and the position of a sensor under test must be understood through characterization and allowed for where relevant. The 0.16°C difference is not simply an error in either instrument. It is the beginning of an uncertainty budget.

Dry blocks are among the most widely used tools in temperature calibration. They are portable, clean, quick to set up, and free of the handling problems that come with stirred liquid baths. That convenience can also be misleading. A dry block is not simply a hot or cold hole in a metal

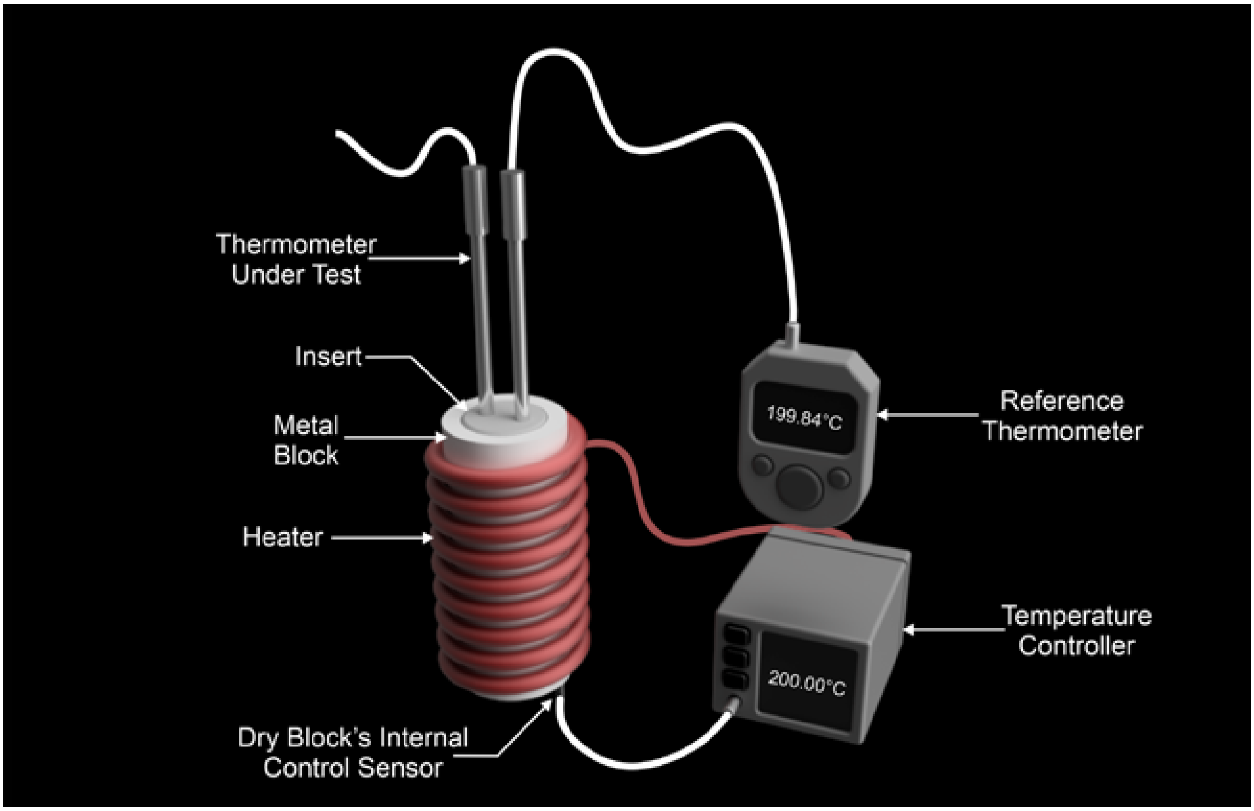

Figure 1. Simplified dry block arrangement. Metal block, insert, reference thermometer, unit under test, and internal control sensor.

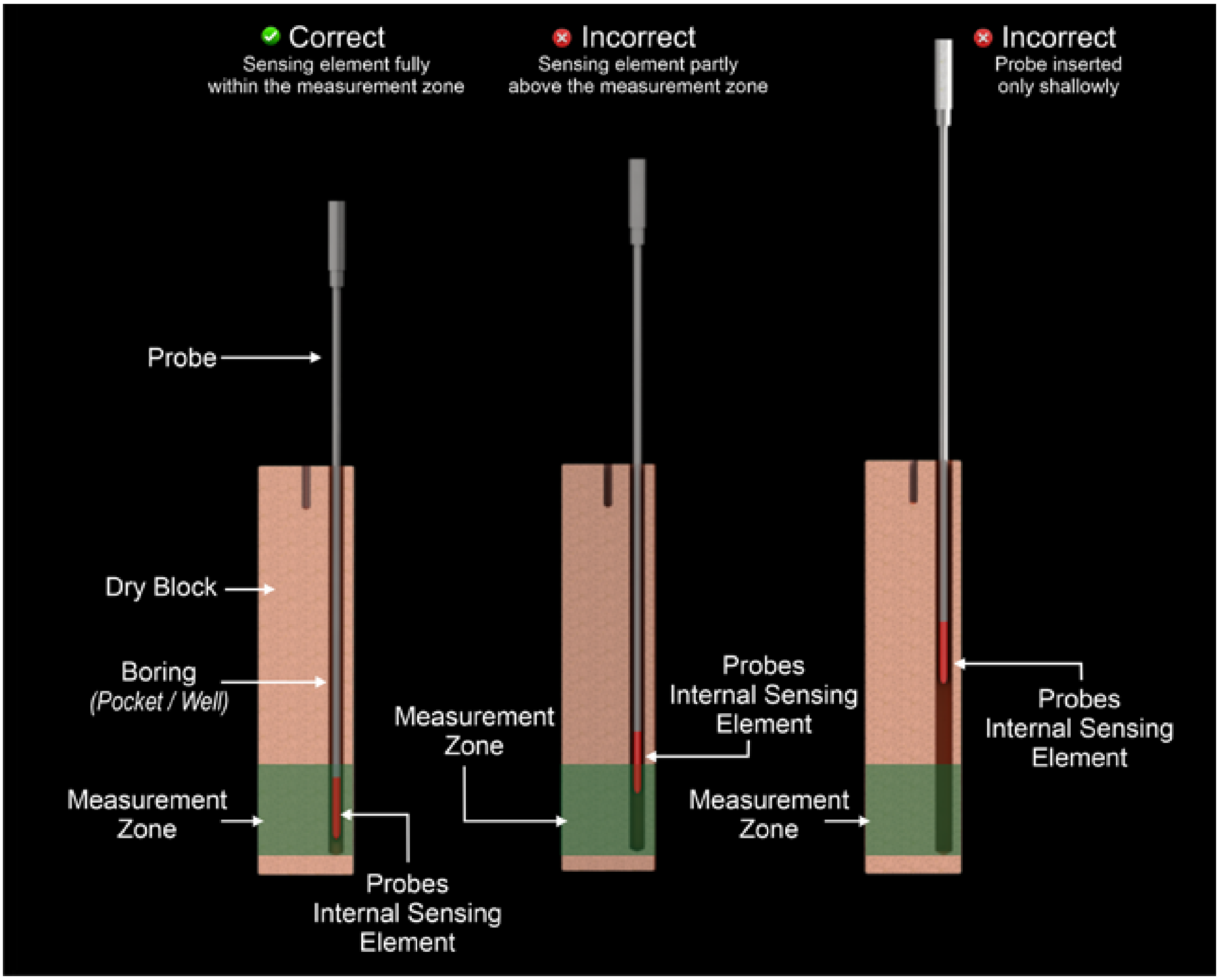

Figure 2. Immersion and sensing element position. Correct placement within the measurement zone, and two incorrect cases.

block. It is a temperature source with a defined measurement zone, real temperature gradients and several uncertainty contributions that need to be understood before a result can be trusted. This article looks at how to use a dry block successfully, rather than what one is.

The principles below are general and apply under any accreditation regime working to ISO/IEC 17025. EURAMET Calibration Guide No. 13, *Guidelines on the Calibration of Temperature Block Calibrators* (CG-13), is used throughout as the primary technical reference. The guide provides practical guidance on calibrating and characterizing dry-block calibrators, including the assessment of temperature distribution, stability, loading effects and the uncertainty associated with their use.

What a Dry Block Does, and Does Not, Tell You

A dry block calibrator is a solid metal block, heated electrically or cooled (often via Peltier modules at lower temperatures), to a temperature set by a controller. Probes are placed into the block, usually via an interchangeable insert that fits inside it, allowing a range of probe types to be inserted into the insert's pockets, wells or borings (the latter being the term used in the EURAMET CG-13 guide).

The controller uses its internal control sensor to drive the block to the set point, and the display shows the temperature reported by that sensor.

This is the first distinction worth making clearly. The display indicates the temperature sensed by the internal control sensor. It does not necessarily indicate the temperature at every point in every boring where a probe might be placed. The block is a temperature source, allowing a thermometer under test to be compared against either the internal control sensor or, better still, a reference thermometer placed in the block alongside it. Assuming the displayed temperature is the temperature the probe is actually experiencing is one of the most common sources of avoidable error.

The Measurement Zone

The temperature in a dry block is not uniform from top to bottom. The block is heated or cooled through its body, the open end loses heat to the surrounding air, and the result is an axial gradient along the boring. The meaningful calibration region is the zone of known temperature homogeneity, whose position is specified, usually the lower end of the boring. Calibration is meaningful only when the sensing element of the thermometer being calibrated actually sits within that zone.

A short sensor and a long sensor placed in the same boring will experience the block differently. A thermometer can appear perfectly stable, and still read the wrong temperature, simply because its sensing element is not where the calibration assumes it to be.

Immersion, Probe Fit, and Thermal Contact

A dry block transfers heat by conduction through the block, the insert, any air gap, and into the probe. Two things govern the quality of that path: how deep the probe sits, and how well it fits.

Insufficient immersion is one of the largest and least understood sources of error in thermal calibration. Heat flows along the thermometer stem between the measurement zone and the cooler world outside, and that flow biases the temperature the sensing element reaches. A working definition is useful: a thermometer is sufficiently immersed when further immersion produces no change in the indicated temperature, within a constant environment. If raising the probe slightly changes the reading significantly, then the immersion depth is likely to be insufficient.

Fit matters for the same reason. As a practical guide, the thermometer pocket should be no more than about 0.5 mm larger than the thermometer diameter up to 660°C, and no more than about 1.0 mm above that. In practice this means choosing the closest insert that still allows safe insertion and removal, keeping borings and inserts clean, not forcing probes, and treating unusual geometries with care. Short probes, surface sensors, angled probes, and large diameter assemblies do not behave like a well fitted straight probe, and should be considered individually.

Practical issue	Likely metrology effect	Good practice response
Probe too loose in the insert	Poor thermal contact, increased uncertainty	Use a closer fitting insert
Probe not deep enough	Stem conduction error	Confirm the sensing element sits in the measurement zone
Too many probes loaded	Loading effect, altered temperature distribution	Evaluate loading, or reduce the number of probes
Reading taken too soon	Stability error	Allow adequate soak time
Relying only on the controller display	Possible offset from true zone temperature	Use a calibrated reference thermometer
Mixed probe types and diameters	Different response and conduction behavior	Treat each probe design separately

Table 1. Common dry block problems and good practice.

Stability and Stabilization or Soak Time

The controller may report that the block is at set point well before the inserted probes have reached equilibrium. Set point stability is a property of the calibrator; the time for the probe to reach stability is a property of the whole assembly, including the probe's mass, its sheath, and the quality of its fit. Larger probes, heavier sheaths, and loose inserts all take longer.

A common error is to begin recording as soon as the display reaches set point, when the indicated value may still move for some minutes. The direction of approach matters too, since arriving at the set point from below rather than from above can reveal hysteresis and thermal lag. Good practice is to wait for both reference and test readings to settle, then capture a short series of readings rather than a single value. This discipline matters most on site, where time pressure is greatest.

Why Use a Reference Thermometer?

The internal control sensor does its job, which is to help control the block. It does not represent every boring or every position perfectly, and the deviation between what it shows and what the measurement zone realizes is exactly the quantity that calibration of the block exists to establish. The more defensible arrangement compares the thermometer under test to a calibrated reference thermometer situated alongside it. Traceability is then carried by the reference thermometer and its readout, together with the method and the uncertainty budget. Returning to the opening example, a block displaying 200.00°C against a reference reading of 199.84°C should be worked from the reference value, with appropriate uncertainty.

Characterization Supports the Calibration Uncertainty

It is tempting to treat characterization and calibration as separate, or even competing, activities. This approach is unhelpful. Characterization is the evidence that makes the calibration uncertainty meaningful: a previous characterization of the device is necessary for associating the uncertainties of the calibration.

The two answer different questions. Calibration establishes the relationship between the indicated temperature, whether from the block display or a reference thermometer, and the temperature realized in a specified measurement zone, expressed as a deviation with an uncertainty. Characterization investigates the thermal behavior behind that relationship: the axial gradient along the boring, the differences between borings, the effect of loading, and the stability with time. Those results are not background detail. They are the input quantities for the uncertainty budget. Without them, a calibration can still produce a correction, but the stated uncertainty may be optimistic and poorly supported. This is why laboratories accredited to ISO/IEC 17025 are expected to summarize the axial distribution, boring differences, loading effects, and stability behind a reported result.

Element	Question it answers	How it supports the result
Axial and radial characterization	How uniform is the temperature field across the relevant borings and depths?	Provides uncertainty components for gradients and boring differences
Stability and loading checks	How much does the realized temperature change with time or probe loading?	Provides components for time stability and normal use
Comparison calibration of the thermometer under test	What correction does the thermometer under test require at each calibration point?	Combines reference value, corrections, and characterized source behavior

Table 2. How characterization supports calibration uncertainty.

Uncertainty in Plain Sight

A full uncertainty budget is beyond the scope of an introductory article, but the contributors are worth naming, because most are physical effects already discussed rather than abstract statistical terms. A comparison calibration in a dry block typically draws on the reference thermometer and its readout, the drift of that reference, the axial non-uniformity along the boring, radial or boring to boring differences, loading effects, stability with time, heat conduction along the stem, hysteresis between increasing and decreasing temperature, and the resolution and repeatability of the indicator in use.

The relative size of these terms changes with temperature, and this is where a data sheet accuracy figure can mislead. Near ambient, the budget may be dominated by the reference thermometer and the indicator, with an expanded uncertainty of a few tenths of a degree. At the upper end of the range, axial gradients and stem-conduction effects can become dominant. Depending on the block, probe, insertion geometry and method, the resulting expanded uncertainty can increase to several degrees. A headline accuracy specification does not, on its own, show how the practical uncertainty changes across the range.

A Practical Checklist

- Select a dry block suited to the temperature range and the uncertainty the task actually requires.
- For traceable low uncertainty results use a calibrated reference thermometer.
- Choose inserts that fit the probes closely, and confirm the sensing element reaches the measurement zone.
- Allow adequate stabilization and soak time before recording, judged from the probes, not the display.
- Record set point, reference reading, unit under test reading, immersion depth, insert used, and ambient conditions.
- Apply corrections where appropriate, and do not claim an uncertainty the method cannot support.

Conclusion

Used casually, a dry block can give a number that looks more certain than it is. Used carefully, with a suitable reference thermometer, attention to the measurement zone, and an honest uncertainty budget built from thermal surveys, it becomes a practical and powerful tool for traceable temperature calibration. The strengths of portability, speed, and cleanliness are genuine. The limitations are manageable, provided the user pays attention to where the sensor actually sits, how heat moves through it, and what the stated uncertainty really rests on.

Further Reading

[1] ISO/IEC 17025:2017, *General Requirements for the Competence of Testing and Calibration Laboratories.*

[2] JCGM 100:2008, *Evaluation of Measurement Data: Guide to the Expression of Uncertainty in Measurement (GUM).*

[3] EURAMET, *Calibration Guide No. 13: Guidelines on the Calibration of Temperature Block Calibrators*, Version 4.0, 2017.

[4] *Supplementary Information for the International Temperature Scale of 1990*, BIPM.

[5] J. V. Nicholas and D. R. White, *Traceable Temperatures: An Introduction to Temperature Measurement and Calibration*, 2nd ed., Wiley.

[6] J. P. Tavener, "Temperature Calibration: Depths of Immersion," *2006 Test and Measurement Conference*, available at www.isotech.co.uk

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On the Probabilistic Interpretation of Type A Uncertainty: A Proposal for Normalization of Student's t Distributions

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The Guide to the Expression of Uncertainty in Measurement (GUM) [1] and its Supplement 1 based on Monte Carlo propagation (GUM-S1) [2] currently coexist as two conceptual frameworks that are partially compatible but not equivalent. This work analyzes an operational discrepancy that appears when Type A uncertainty contributions are represented by Student's t distributions with finite degrees of freedom in Monte Carlo simulations. It is shown that the usual parametrization adopted in the Monte Carlo supplement implicitly breaks the classical interpretation of the combined standard uncertainty as the true RMS standard deviation of the propagated distribution. Based on this observation, a renormalization of the Student's t distribution is proposed that simultaneously preserves: (i) the heavy-tail structure associated with finite degrees of freedom, (ii) the interpretation of the combined standard uncertainty as the RMS-equivalent standard deviation, and (iii) the operational consistency of Monte Carlo propagation of uncertainties between laboratories.

1. Introduction

The evaluation of uncertainty associated with Type A contributions and finite degrees of freedom has been the subject of extensive discussion within the metrological community for several decades. The conventional GUM framework combines individual uncertainty components through the law of propagation of uncertainty and, when necessary, estimates an effective number of degrees of freedom using the Welch–Satterthwaite formula [1,3,4,5,6]. The resulting expanded uncertainty is then commonly obtained from the corresponding Student's t distribution. The classical GUM philosophy consists of:

- evaluating individual standard uncertainties,
- propagating them through linearization,
- obtaining a combined standard uncertainty, and
- applying a coverage factor k in order to obtain the expanded uncertainty.

Within this framework, the usual intuitive interpretation is that:

- u_C represents the RMS dispersion of the measured quantity, and
- k represents the number of "sigmas" required to achieve a given coverage probability.

However, the introduction of Supplement 1 to the GUM based on Monte Carlo propagation [2] profoundly modifies this interpretation. The supplement proposes explicitly representing complete probability distributions and propagating them numerically, partially abandoning the summarized paradigm based on [u_C, k]. The present work tries to show that this transition is not conceptually neutral.

Several authors have pointed out that the GUM approach may exhibit counterintuitive behaviour under certain conditions. In particular, Ballico [8] described a paradoxical situation in which the addition of an uncertainty component with infinite degrees of freedom may lead to an increase in the coverage factor. This observation triggered a broader discussion regarding the validity and interpretation of the Welch–Satterthwaite approximation and the use of Student's t distributions in uncertainty evaluation.

Hall and Willink [7] analysed the behaviour of the Welch–Satterthwaite approach from a probabilistic perspective and concluded that the resulting coverage intervals remain statistically consistent, even in situations where their behaviour may appear unintuitive. More recently, Huang [9] revisited the Ballico paradox and argued that the observed inconsistencies originate primarily from the use of t-based coverage intervals rather than from the Welch–Satterthwaite approximation itself. Several alternative formulations have subsequently been proposed to address these issues while preserving the desired coverage probability.

The present work does not seek to replace either the Welch–Satterthwaite approximation or the Student's t framework. Instead, it focuses on a different aspect of the problem: the interpretation of the combined standard uncertainty when a Student's t distribution is represented explicitly, as advocated by the Monte Carlo framework of GUM Supplement 1 [2]. Under the conventional parametrization, the standard deviation of the resulting Student's t distribution exceeds the combined standard uncertainty for finite degrees of freedom. Consequently, the quantity traditionally interpreted as a standard uncertainty no longer coincides with the root-mean-square (RMS) dispersion of the propagated distribution.

This paper explores an alternative normalization of the Student's t distribution intended to preserve both its heavy-tail behaviour and the RMS interpretation of the combined standard uncertainty. The proposed approach is not presented as a replacement for the conventional GUM methodology but rather as an alternative operational parametrization aimed at improving consistency between classical GUM calculations and MC-based uncertainty propagation. Such consistency may become increasingly relevant in future metrological infrastructures involving the exchange of probabilistic information, digital calibration certificates [10], and the direct propagation of complete probability distributions between laboratories [11,12].

Unlike previous proposals, which replace the t-based interval or redefine the uncertainty estimator, the present work preserves the Student's t framework and focuses on its normalization in order to maintain RMS consistency.

2. Student's t Distributions in the Classical GUM

Let us consider a series of n observations with mean $\bar{x}$ and experimental standard deviation σ. When the population standard deviation is unknown, the statistic follows a Student's t distribution with $\nu = n - 1$ degrees of freedom. The classical GUM then uses:

$$u_C = \frac{\sigma}{\sqrt{n}}$$

together with a coverage factor k = t(p,ν) obtained from Student's t tables or from the most popular programming languages or spreadsheets. For example, for n = 5 (i.e. ν = 4) and a confidence level of 95.45%, one obtains approximately k ≈ 2.87. Therefore:

$$U = 2.87 \cdot u_C$$

3. Operational Discrepancy Observed in Monte Carlo Simulations

Suppose now that this contribution is to be represented explicitly through Monte Carlo simulation. The natural parametrization derived from GUM-S1 would be:

$$X = \bar{x} + u_C \cdot T_\nu$$

However, the Student's t distribution does not have unit variance. For ν > 2:

$$\mathrm{Var}(T_\nu) = \frac{\nu}{\nu - 2}$$

Therefore:

$$\sigma(X) = u_C \cdot \sqrt{\frac{\nu}{\nu - 2}}$$

This implies that $\sigma(X) > u_C$. For example, for = 4, $\sigma(X) = 1.41 \cdot u_C$.

In many practical metrological contexts, users intuitively interpret the reported standard uncertainty as the RMS standard deviation of the associated probability distribution. This leads to an important conceptual operational discrepancy: the classical GUM interprets u_C as the standard uncertainty, whereas a Monte Carlo simulation directly based on Student's t distribution produces an RMS-equivalent standard deviation larger than u_C. Consequently, the factor k = 2.87 no longer represents "2.87 actual standard deviations." Instead, 95.45% of simulated occurrences lie within the interval $[\bar{x} - 2.03 \cdot \sigma(X), \bar{x} + 2.03 \cdot \sigma(X)]$.

4. Operational Consequences

The previous operational discrepancy is not merely philosophical, and it does not only affect to Type A measurements. Suppose a laboratory transmits to its customer the following parameters, describing the probability density function (PDF) assumed for the device under test, normally by making use of the GUM: u_C, $k \neq 2$ and finite ν_{eff}. The customer subsequently reconstructs the PDF as a Type B contribution using:

$$X = \bar{x} + u_C \cdot T_{\nu\_eff}$$

In such a case, $\sigma(X) > u_C$. Therefore, if the customer directly uses this MC-generated cloud of points as an input variable in his or her new simulation:

- an RMS dispersion larger than the declared standard uncertainty of the traveling standard will be propagated,
- the effective uncertainty will grow potentially, and
- the physical interpretation of u_C as an RMS sigma will no longer hold.

This effect appears whenever finite degrees of freedom are involved. The problem arises whenever an input random variable is generated with coverage factor $k \neq 2$ (either a Type A contribution or a Type B coming from a calibration certificate). Besides, it can be encountered when trying to describe the output PDF obtained as a result of a Monte Carlo simulation.

5. Conceptual Differences between the Classical GUM and the Monte Carlo Supplement

The classical GUM and the Monte Carlo supplement rely on different probabilistic philosophies. The classical GUM considers:

- an estimated standard uncertainty u_C,
- an uncertainty associated with the estimation of u_C itself,
- a Welch–Satterthwaite correction, and
- an external coverage factor $k = t(p,\nu_{eff})$, where 't' stands for Student's t.

Whereas the Monte Carlo supplement adopts a different philosophy:

- it does not work with the "uncertainty of the uncertainty,"
- it directly uses complete probability distributions, and
- it absorbs uncertainty about u_C into the tails of the distribution itself.

Thus, the supplement explicitly recognizes $\sigma(X) > u_C$, which implicitly breaks the usually assumed equivalence $u_C = \sigma(X)$.

6. Proposal for Renormalization of the Student's t Distribution

In order to preserve simultaneously: (i) the heavy tails associated with finite degrees of freedom, particularly when the number of measurements is low; (ii) the physical interpretation of u_C as the true RMS standard deviation; and (iii) the consistency of Monte Carlo propagations through the users, it is proposed here to use a Student's t distribution normalized to unit variance. Let us define:

$$T_\nu(\text{normalized}) = T_\nu \cdot \sqrt{\frac{\nu - 2}{\nu}}$$

By definition, the variance of this random variable is unity:

$$\operatorname{Var}\left(T_\nu(\text{normalized})\right) = 1$$

Therefore, any Monte Carlo contribution based on the Student's t PDF would be defined as:

$$X = \bar{x} + u_C \cdot T_\nu(\text{normalized}) = \bar{x} + u_C \cdot T_\nu \cdot \sqrt{\frac{\nu - 2}{\nu}}$$

With this definition, $\sigma(X) = u_C$, exactly.

7. Redefinition of the Coverage Factor

The previous proposal implies that the coverage factor no longer coincides with the raw tabulated Student's t quantile. The new effective coverage factor becomes:

$$k' = t(p, \nu) \cdot \sqrt{\frac{\nu - 2}{\nu}}$$

For $\nu = 4$ and a confidence level CL = 95.45%, one obtains approximately $k' \approx 2.03$, as mentioned above when noticing that 95.45% of generated occurrences lie within a margin of $\pm 2.03 \cdot \sigma(X)$ around the mean value.

This new factor has a clear physical interpretation: the true number of RMS standard deviations required to cover the desired interval, which coincides with the intuitive concept most metrologists have about the results expressed in their calibration certificates.

Unlike the classical factor $k = t(p,\nu)$, the new proposed factor decouples tail geometry and RMS scale, preserves the physical interpretation of u_C and avoids artificial variance inflation in MC-based propagation of uncertainty.

The following table presents the k and k′ factors as a function of the effective number of degrees of freedom, together with a graphical representation of the k′ factor, the k factor as defined in the GUM document for a level of confidence of 95.45%, and the percentage reduction resulting from the use of k′ instead of k.

Note that, if consistency between the GUM approach and the Monte Carlo Supplement 1 approach is to be preserved, the same coverage factor should be used so that uncertainty calculations yield the same results. Nevertheless, in most high-precision measurements the effective number of degrees of freedom is large — or, equivalently, the relative weight of Type A contributions is rather moderate with respect to the overall uncertainty budget. Consequently, the proposed modification will only affect those measurements in which the dominant contribution is repeatability and, additionally, the number of measurements — and therefore the number of degrees of freedom — is small.

8. Example I: Type A Student's t Combined with a Type B Gaussian

Here we present the result of the combination of two contributions. A Type A contribution due to repeatability (5 measurements, i.e. the number of degrees of freedom is 4) with a variance equal to 0.5, combined with a Type B contribution assumed to be Gaussian (infinite degrees of freedom) and with the same variance.

Dof	k	k'	(k'-k)/k	Dof	k	k'	(k'-k)/k
3	3.31	1.91	-42.3%	22	2.12	2.02	-4.7%
4	2.87	2.03	-29.3%	23	2.11	2.02	-4.4%
5	2.65	2.05	-22.5%	24	2.11	2.02	-4.3%
6	2.52	2.05	-18.4%	25	2.11	2.02	-4.1%
7	2.43	2.05	-15.5%	30	2.09	2.02	-3.4%
8	2.37	2.05	-13.4%	35	2.07	2.01	-2.9%
9	2.32	2.05	-11.8%	40	2.06	2.01	-2.5%
10	2.28	2.04	-10.6%	45	2.06	2.01	-2.2%
11	2.25	2.04	-9.5%	50	2.05	2.01	-2.0%
12	2.23	2.04	-8.7%	55	2.05	2.01	-1.8%
13	2.21	2.03	-8.0%	60	2.04	2.01	-1.7%
14	2.20	2.03	-7.4%	65	2.04	2.01	-1.6%
15	2.18	2.03	-6.9%	70	2.04	2.01	-1.4%
16	2.17	2.03	-6.5%	75	2.03	2.01	-1.3%
17	2.16	2.03	-6.1%	85	2.03	2.01	-1.2%
18	2.15	2.03	-5.7%	100	2.03	2.00	-1.0%
19	2.14	2.02	-5.4%	120	2.02	2.00	-0.8%
20	2.13	2.02	-5.1%	160	2.02	2.00	-0.6%
21	2.13	2.02	-4.9%	200	2.01	2.00	-0.5%

Table 1. Factors k' and k as a function of effective degrees of freedom, for CL = 95.45%.

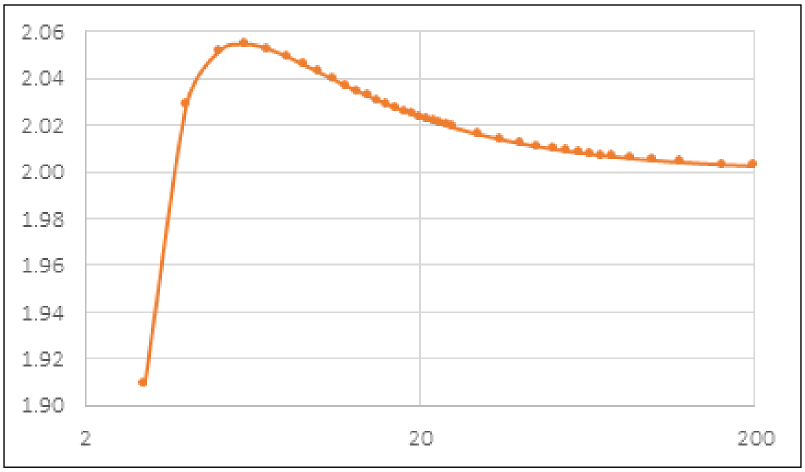

Figure 1. Factor k' as a function of effective degrees of freedom, for CL=95.45%.

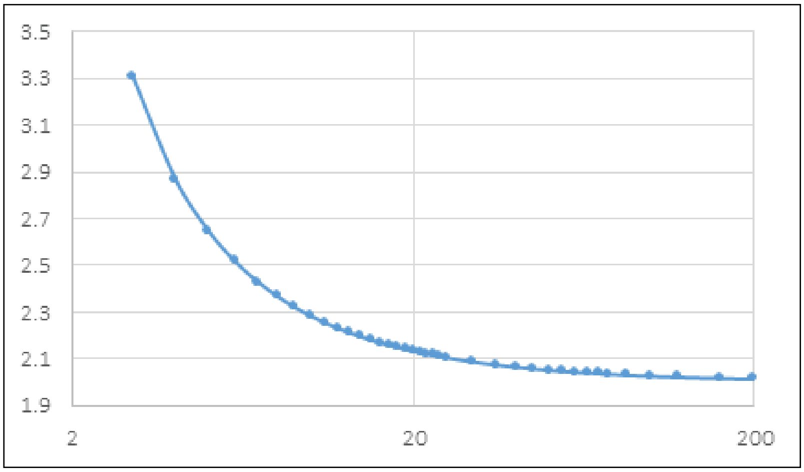

Figure 2. Factor k as a function of effective degrees of freedom, for CL=95.45%.

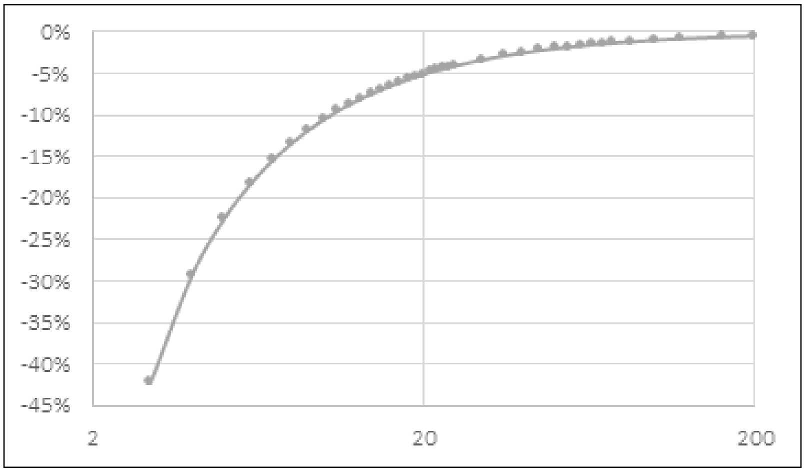

Figure 3. Percentage reduction in k' with respect to k vs. v_{eff}, for CL=95.45%.

According to the GUM, the combination of both variances yields a combined standard uncertainty of unity, and the effective number of degrees of freedom according to the Welch–Satterthwaite formula is given by:

$$\nu_{\text{eff}} = \nu_A \cdot \frac{\left(\sqrt{u_A^2 + u_B^2}\right)^4}{u_A^4} = 4 \cdot \frac{(\sqrt{0.5 + 0.5})^4}{(\sqrt{0.5})^4} = 16$$

Applying the GUM approach would lead to a coverage factor k = 2.17 for a confidence level CL = 95.45% (which would yield an expanded uncertainty of 2.17), whereas the proposed k′ factor, for an effective number of degrees of freedom ν_{eff} = 16 and the same CL, is k′ = 2.03. The reduction observed in expanded uncertainty from 2.17 to 2.03 represents a percentage decrease of 6.5%, as indicated in the tables in the previous section.

Solving the same problem by means of stratified Monte Carlo simulation for N = 107, the lower and upper quantiles for CL = 95.45% are found to be approximately equal to 1.99, while the standard deviation is approximately 1.00. Therefore, the Monte Carlo value obtained for the coverage factor k′, namely 1.99, is considered an acceptable approximation to the theoretical value of k′.

Figure 4 shows a histogram of the combination of both contributions, together with the theoretical value of a Student's t distribution for an effective number of degrees of freedom ν_{eff} = 16. Note that determination of a particular distribution for the output random variable with Monte Carlo is not strictly needed.

In Table 2, the computed parameters for the combination of the two above contributions are shown. One of the goals of this proposed k′ is that both the analytical computations made with the GUM and those made by Monte Carlo are consistent with each other and do coincide within the desired degree of accuracy (which is dependent on the number of Monte Carlo simulations).

Although the agreement between Monte Carlo results and the predicted coverage factor k′ is not exact, this can be attributed to differences in the underlying modelling assumptions. The Monte Carlo method propagates the full probabilistic structure of the input quantities to the output without imposing a specific analytical form. In contrast, the GUM approach, including the use of an effective coverage

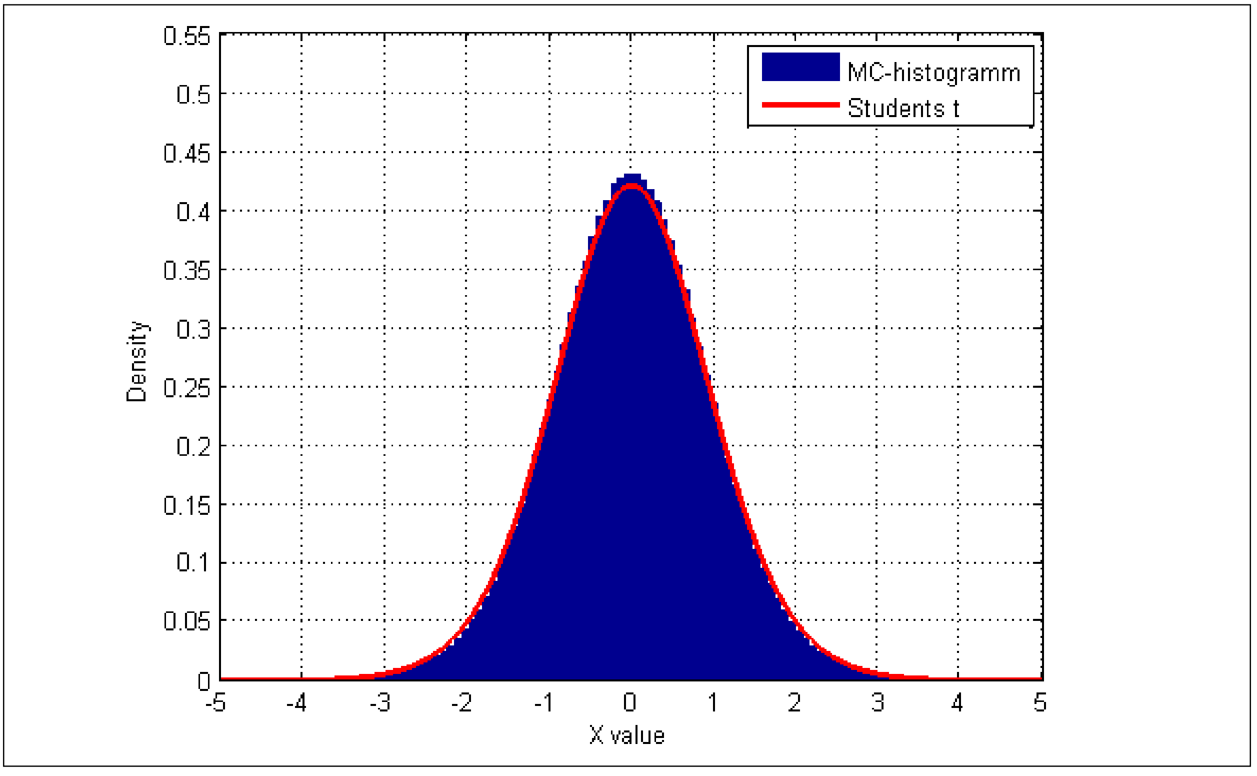

Figure 4. Histogramm vs.Student's t distribution with v_{eff} = 16.

Contribution	Probability density function	Degrees of freedom	Standard uncertainties ui
Type A	Student's t	4	0.701
Type B	Gaussian	∞	0.701
u_C (GUM)	Student's t	16	1.00
u_C (Monte Carlo)	-	-	≈ 1.00
Uncertainty	**Coverage factor (CL = 95.45%)**		**Uncertainty U**
$U_{expanded}$ (GUM)	k = 2.17		2.17
$U_{expanded}$ (GUM with proposed k')	k' = 2.03		2.03
$U_{expanded}$ (Monte Carlo)	k' ≈ 1.99		≈ 1.99

Table 2. Type A and Type B contributions and its combination by GUM and Monte Carlo.

factor k', assumes that the output distribution can be approximated by a Student's t distribution with an effective number of degrees of freedom.

This approximation may not hold in general, particularly for a small number of input quantities or for non-normal and heterogeneous input distributions. In such cases, the conditions required for the Central Limit Theorem are not fully satisfied, and the resulting output distribution may deviate from a Student's t form. Consequently, the effective degrees-of-freedom approximation may not accurately represent the true distribution, whereas Monte Carlo provides a more general numerical characterization of the output uncertainty.

9. Example II: Dominant Student's t Combined with Gaussian

Assuming the same Type A contribution with 4 degrees of freedom, now combined with a much smaller Gaussian, and according to Welch-Satterthwaite:

$$\nu_{eff} = \nu_A \cdot \frac{\left(\sqrt{u_A^2 + u_B^2}\right)^4}{u_A^4} = 4 \cdot \frac{\left(\sqrt{0.9375 + 0.0625}\right)^4}{\left(\sqrt{0.9375}\right)^4} = 4.5$$

By comparison between examples I and II, as a general observation it may be stated that the closer the resulting distribution is to a pure or ideal Student's t distribution, the more accurate the simulation becomes, and the closer the theoretical coverage factor (k') is to the value obtained by Monte Carlo simulation.

In our opinion, Example I represents a hybrid behaviour between a Student's t distribution and a Gaussian distribution, whose response may not strictly follow an exact Student's t distribution. This could possibly be explained by the fact that neither the Welch–Satterthwaite approximation nor the central limit theorem are fully applicable when only two uncertainty components are involved.

10. Implications for Calibration Certificates

The previous observations suggest that the classical paradigm based only on the triad [y, u_C, k] for a given confidence level CL, may be insufficient to completely describe uncertainty in Monte Carlo environments. A hybrid approach is proposed consisting of:

I. Maintaining the classical certificate for regulatory, auditing and interoperability reasons.
II. Adding explicit probabilistic information: e.g. histograms, output PDF either in graphic or in formulas, computed quantiles and Monte Carlo samples.
III. Eventually considering multivariate distributions and correlated samples.

The graphical representation of the output pdf would immediately allow visualization of asymmetries, multimodality, heavy tails, deviation from Gaussian- as well as Student's t-assumption and truncation effects.

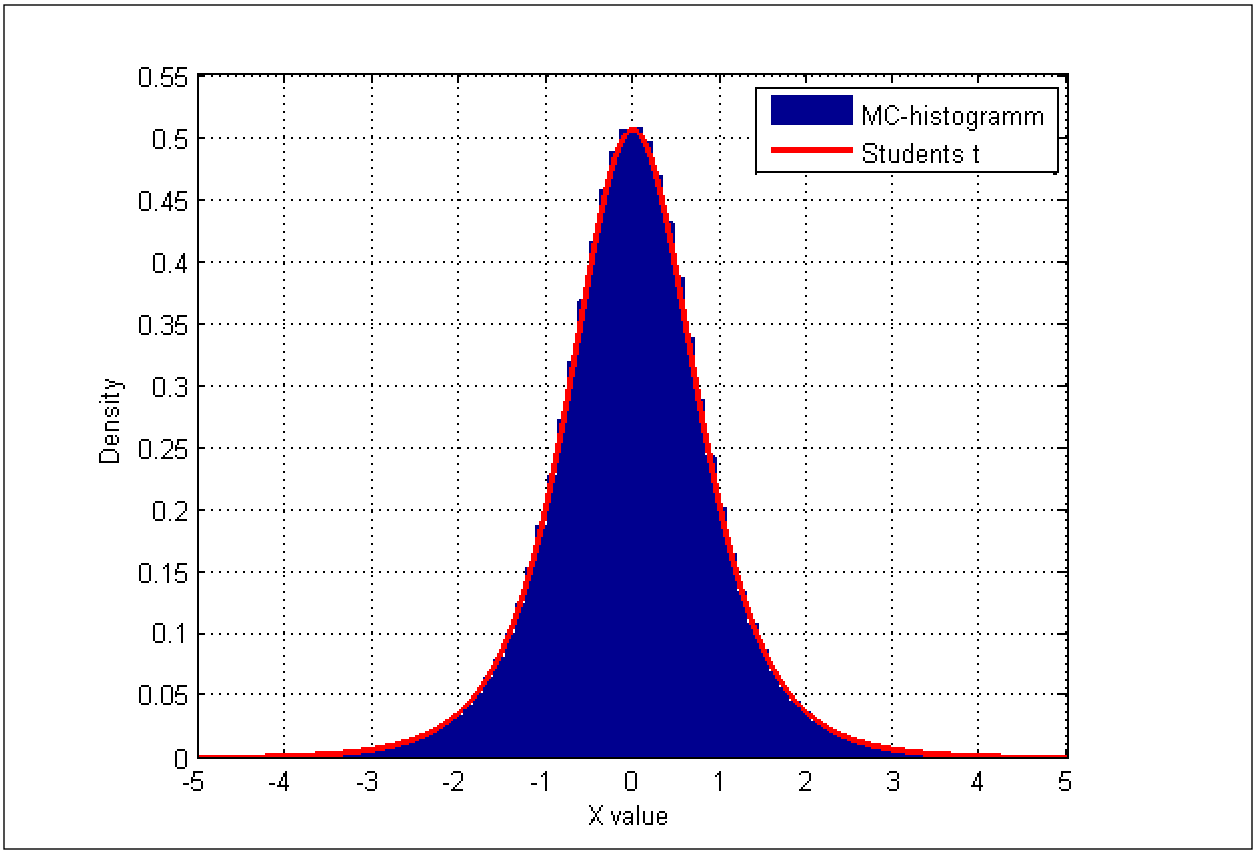

Figure 5. Histogramm vs.Student's t distribution with v_{eff} = 4.

Contribution	Probability density function	Degrees of freedom	Standard uncertainties ui
Type A	Student's t	4	0.968
Type B	Gaussian	∞	0.250
u_C (GUM)	Student's t	4	1.00
u_C (Monte Carlo)	-	-	≈ 1.00
Uncertainty	**Coverage factor (CL = 95.45%)**		**Uncertainty U**
$U_{expanded}$ (GUM)	k = 2.87		2.87
$U_{expanded}$ (GUM with proposed k')	k' = 2.03		2.03
$U_{expanded}$ (Monte Carlo)	k' ≈ 2.02		≈ 2.02

Table 3. Type A (dominant) and Type B contributions and its combination by GUM and Monte Carlo.

11. Towards Full Probabilistic Traceability

The current paradigm of metrological traceability is based on certificates summarized by a small set of parameters such as [y, u_C, k, ν_{eff}]. However, the development of massive Monte Carlo simulation techniques and the increase in computational power allow imagining an alternative scenario based exclusively on explicit probabilistic propagation.

In this possible paradigm, informally referred to here as "fully MC-based propagation of uncertainties," calibration laboratories would no longer transmit only assigned value, standard uncertainty, coverage factor and effective degrees of freedom. Instead, the certificates would directly contain numerical samples, these being representative (and necessary for) the complete subsequent distribution (propagation) of the measurand.

In other words, the calibration result would cease to be expressed merely as [y ± U] and would instead become a set of samples: {xi} i.e. an array of size N containing a particular simulation of the output random variable x and capable of explicitly representing:

- deviation from Gaussian- as well as Student's t-assumptions,
- asymmetries,
- heavy tails,
- multimodality,
- truncations, and
- even complex nonlinear effects.

Also, an array containing a simulation of the correlation behaviour of, say three random variables x, y and z would be contained in a similar N-size array {[x, y, z]i}. By permuting the index 'i' the user would re-arrange the input array if needed. Note however that it is not necessary to permute the input array in order to combine it with other contributions of the measurement system, just as it is not necessary to rearrange a row of individuals in order to randomly assign them a series of numbers; it is sufficient to permute the numbers themselves.

12. Conclusions

The analysis performed shows that there exists a significant conceptual difference between the classical GUM interpretation of the combined standard uncertainty, and the explicit representation of Student's t distributions within the Monte Carlo supplement. The usual GUM-S1 parametrization implies $\sigma(X) > u_C$ for finite degrees of freedom. Consequently, the RMS standard deviation of the resulting distribution differs from u_C, which may complicate the intuitive and operational interpretation of the combined standard uncertainty as a measure of dispersion.

As an alternative, a renormalization of the Student's t distribution is proposed that preserves the heavy-tail structure, at the same time maintaining $\sigma(X) = u_C$ by definition. This is done by redefining the coverage factor as:

$$k' = t(p, \nu) \cdot \sqrt{\frac{\nu - 2}{\nu}}$$

The proposed approach should be regarded as an alternative operational parametrization rather than as a replacement for the conventional GUM interpretation. In practice, its effect on most calibration and measurement results is expected to be negligible, since high-precision measurements generally exhibit a large effective number of degrees of freedom, causing the conventional and proposed coverage factors to become virtually indistinguishable. Noticeable differences arise only when repeatability constitutes the dominant uncertainty contribution and the associated effective degrees of freedom are small.

The proposed parametrization may be viewed as a practical bridge between the traditional GUM approach and the probabilistic framework introduced by the GUM Supplement 1, helping to ensure that equivalent uncertainty concepts retain the same operational meaning regardless of the propagation method employed. This reformulation is especially attractive in contexts involving subsequent MC-based propagation of uncertainties between laboratories, where RMS consistency of transmitted distributions becomes essential.

Finally, it is suggested that future metrological developments may evolve toward hybrid certificates capable of combining classical traceability, full probabilistic propagation and explicit representations of output distributions.

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

Henry Zumbrun
Morehouse Instrument Company

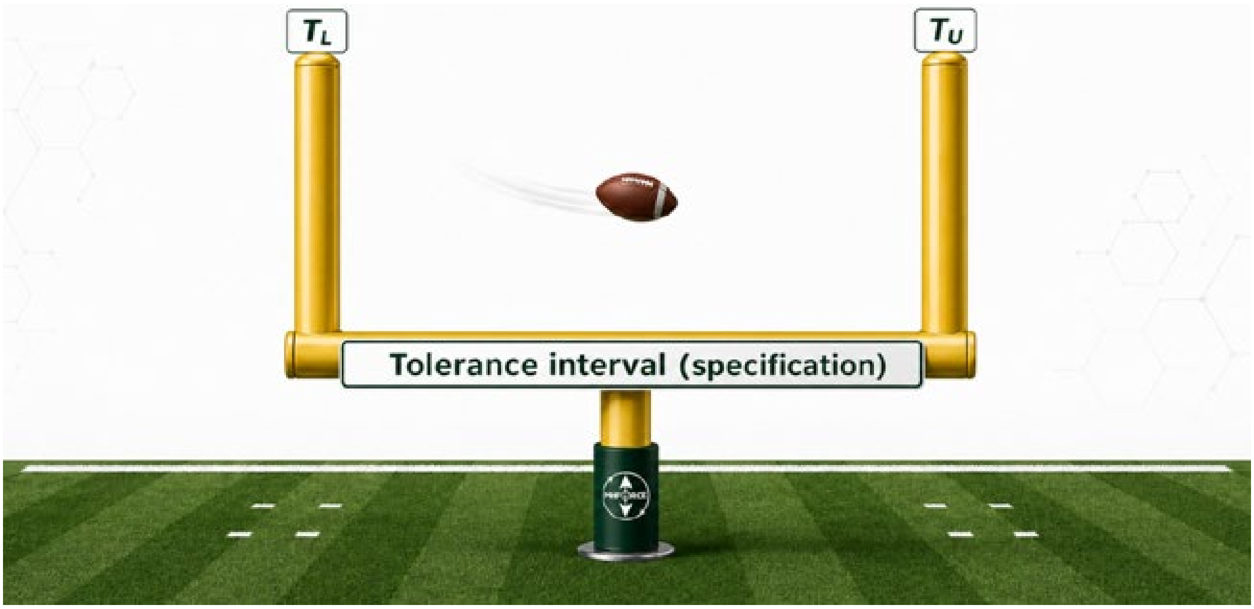

Figure 1. The two uprights are your tolerance limits, T_L and T_U. The ball must pass through the window. Conformity works the same way (JCGM 106:2012 Section 5).

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

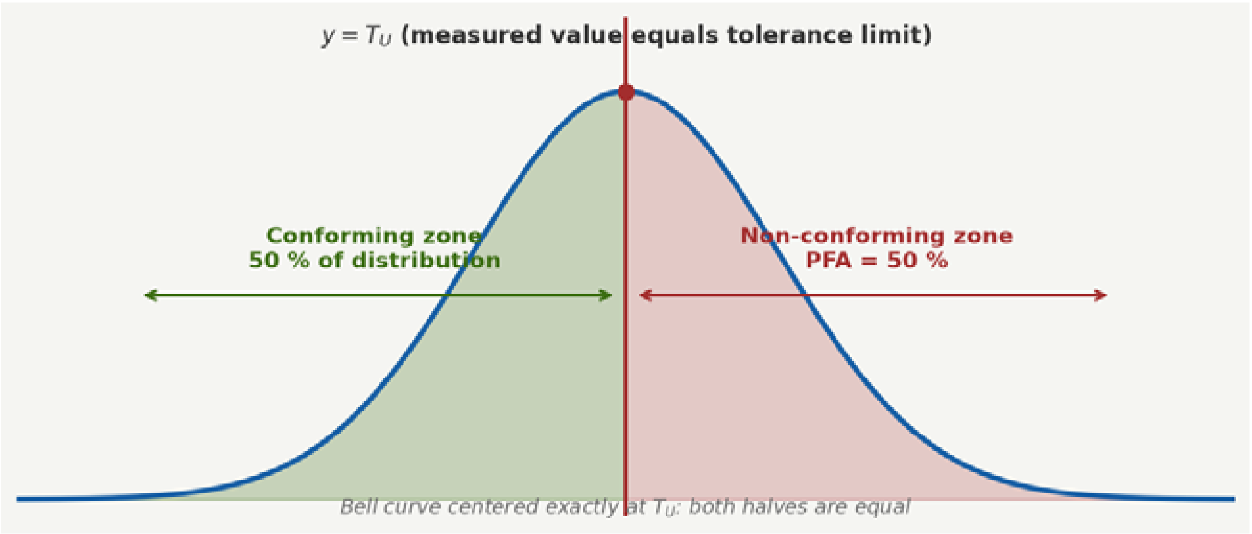

Figure 2. When $y = T_U$, the Gaussian distribution is centered exactly at the tolerance limit. Both halves are equal: conforming zone = 50 %, non-conforming zone = 50 %, PFA = 50 % (JCGM 106:2012 Section 8.3.1.2).

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 little 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 8.1.1 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

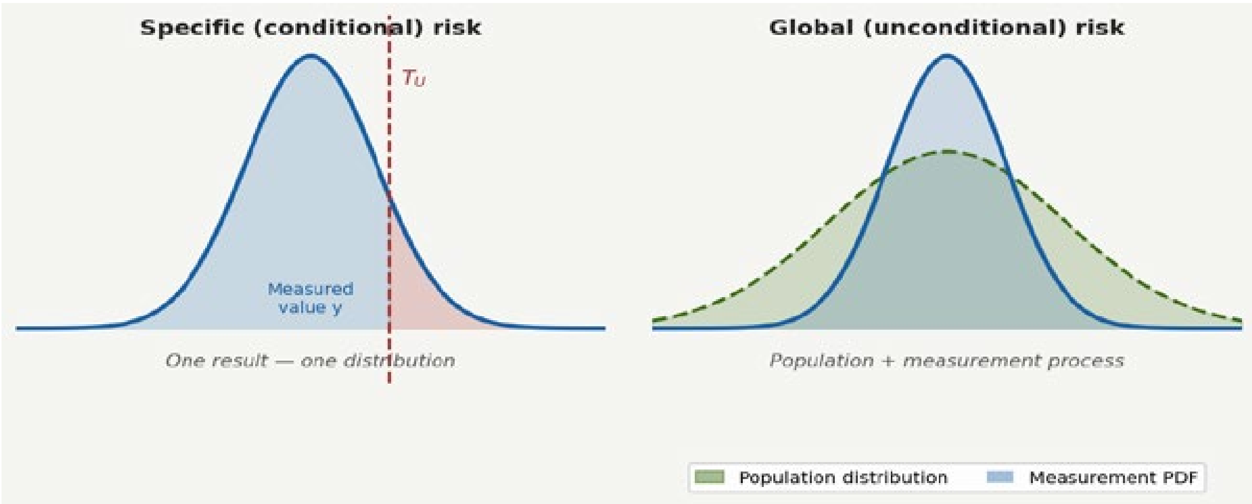

Figure 3. Specific risk (left) uses one distribution centered on the single measurement result. Global risk (right) integrates a joint distribution combining population spread with measurement uncertainty (JCGM 106:2012 Sections 9.4 and 9.5).

> 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

Figure 5 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 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 the acceptance limit A_U is held to 2.5 % because the

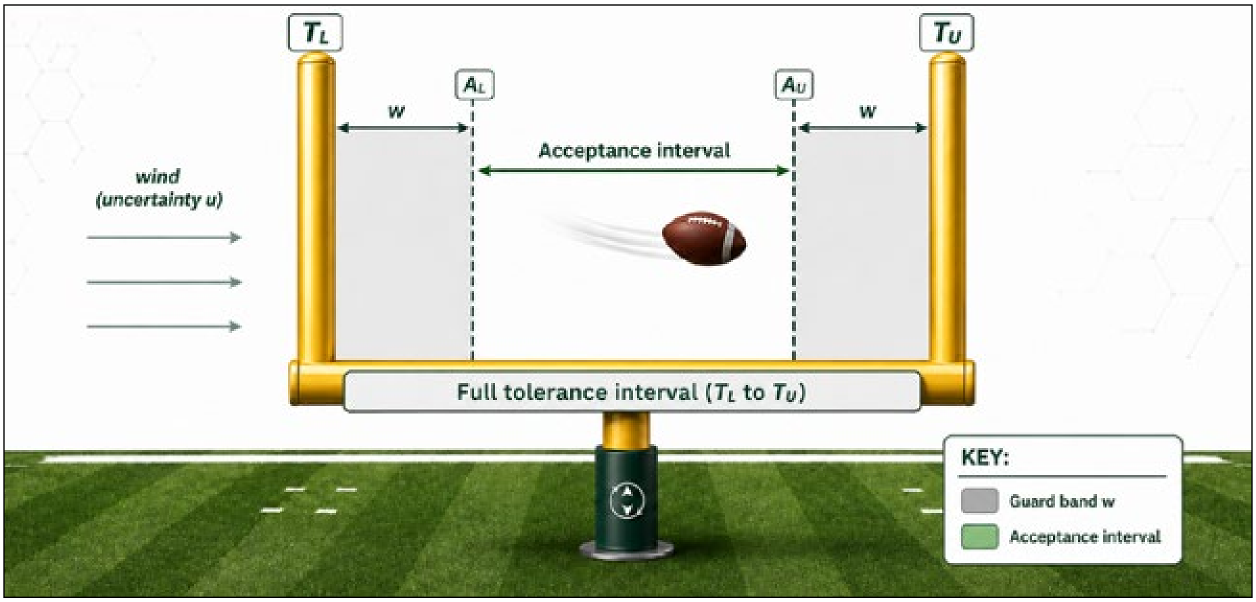

Figure 4. The wind analogy made explicit. The uprights are the tolerance limits and they do not move. Measurement uncertainty is the crosswind. Guard bands of length *w* are set inward from each upright, leaving the acceptance interval the kicker needs to aim within.

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.

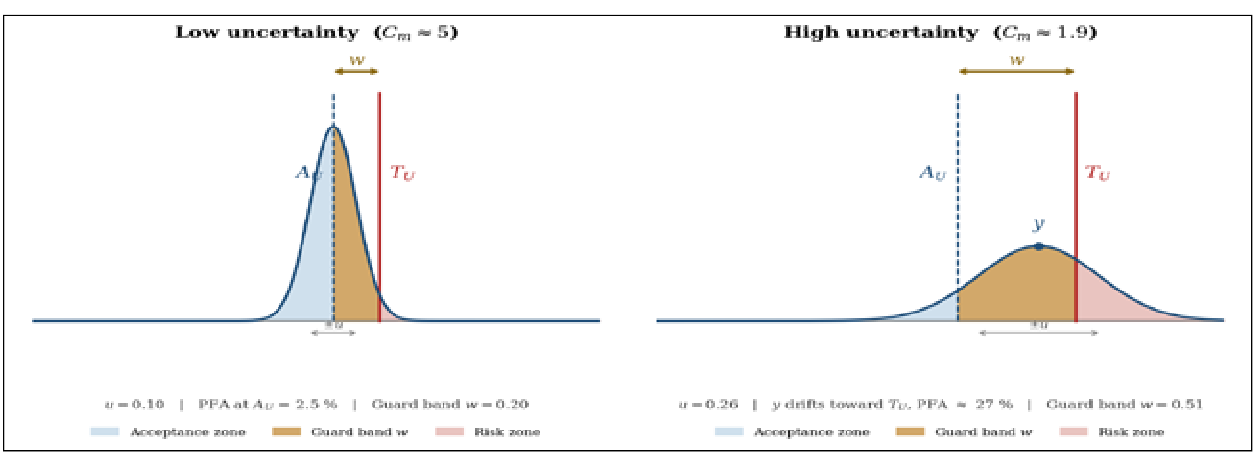

Figure 5. Guard Band Geometry. Left: low uncertainty, small *w*. Right: high uncertainty, wide *w*. PFA at A_U = 2.5 %. The acceptance zone (blue) shrinks as uncertainty grows (JCGM 106:2012 Section 8.3.2).

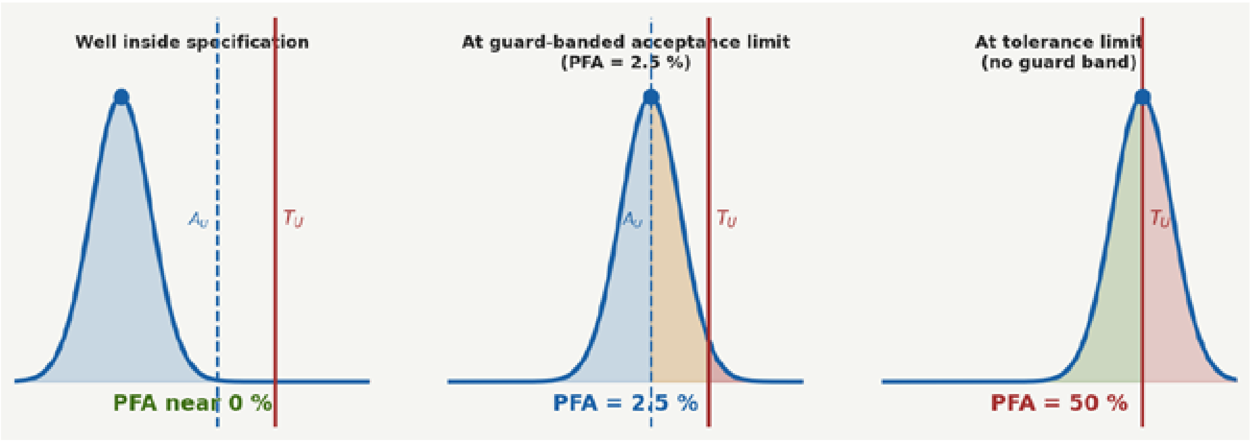

Figure 6. Three measured values, same tolerance interval, same measurement uncertainty. Left: PFA near 0 %. Center: measured value at acceptance limit A_U, PFA = 2.5 % (only a small red tail extends beyond T_U). Right: measured value at tolerance limit with no guard band, PFA = 50 % with equal green 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

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- **ILAC-G8:09/2019:** Guidelines on decision rules and statements of conformity.
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Yokogawa Test & Measurement Releases WT1500 Precision Power Analyzer

Meeting the power measurement needs of high-voltage xEV and renewable energy applications

Tokyo, Japan – July 22, 2026 – Yokogawa Test & Measurement Corporation announces the release on August 19 of the WT1500 Precision Power Analyzer as a new addition to the WT series. The WT series power analyzers are widely used as essential measurement instruments for the development and performance evaluation of powertrains for electric vehicles (xEVs) and renewable energy-related equipment. The new WT1500 features the series' first 2000 V DC input voltage capability and industry-leading measurement accuracy. It also incorporates a space-saving design for ease of use in test environments, resolver signal input support, and multi-unit synchronization. These features enable the WT1500 to meet evolving measurement needs in applications with higher voltages and increasing system complexity.

Development Background

Continued advances in xEV technologies and the growth of the renewable energy market is accelerating demand for evaluation, testing, and production capabilities built around high-voltage equipment. However, when measuring voltages exceed 1500 V, conventional power analyzers require dedicated high-voltage dividers, which can affect measurement accuracy and complicate wiring and equipment installation. In addition, measuring motor efficiency in xEV applications has traditionally required power signals and resolver signals to be measured separately and synchronized later on a PC. Combined with the challenge of fitting measurement instruments into conventional rack-mounted setups or limited desktop test environments, these requirements have made testing and evaluation processes complex and time-consuming.

To address these challenges, Yokogawa Test & Measurement has developed the WT1500, a power analyzer that eliminates the need for high-voltage dividers in systems up to 2000 V while significantly enhancing usability, enabling more efficient and streamlined testing and evaluation workflows.

Main Features

<u>1. High performance for high-voltage, high-precision measurement</u>

The WT1500 delivers the highest level of measurement performance in the WT Series, maintaining outstanding measurement accuracy across a wide range of operating conditions. In addition, two types of input elements are available to suit specific applications, enabling a single instrument to support both the evaluation of high-voltage systems, such as energy storage systems (ESS) and power conversion systems (PCS), and the measurement of the latest xEV motors.

Main specifications:

- Total power accuracy of ±0.038% (DC, 50/60 Hz) and low-power-factor accuracy of ±0.07% of S (apparent power) at 50/60 Hz
- High voltage element supports direct measurement up to 2000 V DC and 300 kHz, ideal for PCS and ESS applications.
- Wide bandwidth element supports up to 1000 V with a 2 MHz bandwidth, crucial for measuring the complex, high-frequency waveforms generated in modern xEV motors.
- Both inputs share a common sensor input and can be mixed in a single unit.

<u>2. System integration and a space-saving design</u>

Despite its compact form factor, which allows easy integration into test facilities, the WT1500 offers a wide range of communication interfaces and remote-control capabilities, enabling flexible connectivity with various testing and evaluation systems. It supports a broad range of applications, from seamless integration into automated evaluation systems to standalone measurement and analysis tasks.

- Supports up to four power measurements and four motor evaluations.
- Supports encoder and resolver signal inputs, IEEE 1588 time synchronization, data output to CAN/CAN FD buses, and low-latency data transmission via UDP communication.
- Equipped with a variety of interfaces that enable remote operation from a PC, external monitor, or tablet, allowing the WT1500 to be used as a standalone measurement instrument. A compact front-panel control interface also simplifies connection and configuration settings.
- A space-saving 2U design (19-inch rack width, approximately 88 mm high) makes it easy to integrate into evaluation system racks and test equipment installations.

<u>3. Scalability for multi-channel measurements</u>

For measurements requiring more than four channels, up to five WT1500 units can be synchronized, enabling 20-channel power measurement. One unit acts as the main controller, directing subunit configuration and consolidating data acquisition. The WT1500 also features up to four unique current input terminals alongside the voltage terminals, providing power for current sensors. These, in combination with a series of new current adapters that are provided as accessories, enable the WT1500 to accommodate a wide variety of sensors: the CT Series penetration-type (D-sub Terminal, 60 A to 2000 A, AC/DC), the CT1000S split-core (BNC, 1000 A, AC/DC), and AC-only current clamp probes (BNC, 50 A and 200 A class).

Major Target Markets

- EV/xEV, automotive
- Power
- Renewable energy (PCS/ESS)

Applications

- Four-channel power measurement, handling both single-phase and three-phase inputs simultaneously, using a PC to manage system configuration and data acquisition
- Measurement of two-system inverter motors and e-Axle systems using dual-WT1500 and single unit setups, respectively.
- Multi-unit simultaneous measurement and high-voltage measurement of ESS and PCS.

For More Information

https://tmi.yokogawa.com/solutions/products/power-analyzers/wt1500-precision-power-analyzer/

Cal Lab Solutions, Inc. Introduces AuditReady™: ISO/IEC 17025 Compliance with Point-by-Point "Audit Ready" Uncertainty Budgets

AURORA, Colo. — June 24, 2026 — Cal Lab Solutions, Inc. introduces the launch of AuditReady™, a new automation feature in Metrology.NET designed to eliminate the stress, complexity, and manual labor associated with ISO/IEC 17025 compliance.

AuditReady™ integrates directly into the Metrology.NET calibration software platform, automatically generating a fully compliant, assessor-approved uncertainty budget for **every single test point** in a calibration run. Crucially, these budgets are delivered as native, fully interactive Microsoft Excel spreadsheets, providing assessors with the transparency they need to review and verify calculations effortlessly.

Traditionally, there has been a significant disconnect between everyday calibration software calculations and the actual uncertainty budgets required for an ISO/IEC 17025 audit. While standard automation software is highly efficient at printing a final, static uncertainty value on a calibration certificate, it does so behind closed doors. The underlying physics, sensitivity coefficients, and GUM (Guide to the Expression of Uncertainty in Measurement) formulas remain locked inside a "black box." So, when an assessor demands to see the exact proof of how a specific point's uncertainty was calculated, lab managers are forced to manually reverse-engineer the data, reconstructing budgets in separate spreadsheets. AuditReady™ bridges this painful gap by aligning day-to-day automated execution with the transparent, open-book proof that assessors expect.

Michael Schwartz, CEO of Cal Lab Solutions, Inc., explains, "Audit season is notoriously stressful for calibration laboratories, largely because proving compliance can feel like solving a mystery for the assessor. With AuditReady™, labs aren't just automating the math they are simplifying the process. By generating native Excel sheets with live, clickable formulas for every single test point, we make the assessor's job incredibly easy. They can see exactly how the uncertainty was calculated, verify the math in seconds, and move on. It completely redefines what it means to be 'audit-proof.'"

Key Features of AuditReady™ Include:

- **Native Excel-Based Budgets:** Generates clean, fully transparent Excel spreadsheets for every test point. Assessors can click on individual cells to inspect active formulas, GUM-compliant calculations, and sensitivity coefficients.
- **Granular, Point-by-Point Accuracy:** Automatically calculates and attaches a unique ISO/IEC 17025 uncertainty budget to every individual test point, avoiding blanket or best-case approximations.
- **Faster, Frictionless Audits:** By presenting data in a familiar, verifiable, and highly organized spreadsheet format, laboratories can significantly reduce assessment times and avoid costly non-conformances (NCRs).
- **Zero-Effort Automation:** Operates entirely in the background of Metrology.NET, requiring no manual data entry, complex math scripts, or extra steps from the calibration technician.
- **Transparency:** Eliminates "black box" worries, giving assessors total confidence that the underlying physics and math are correct and verifiable.

AuditReady™ is now available as a standard update for all Metrology.NET users. Laboratories looking to streamline their ISO/IEC 17025 accreditation process and eliminate audit anxiety can learn more by visiting **www.metrology.net**.

METROLOGY.NET

About Metrology.NET

Metrology.NET® is a modular, automation-first calibration software platform designed by Cal Lab Solutions, Inc. Built to handle the world's most complex measurement challenges, Metrology.NET provides calibration laboratories with the tools, scalability, and metrological rigor required to stay ahead in an evolving industry.

Additel Launches the New ADT710 Automated Gauge Calibration System

Brea, California — June 3, 2026 — Additel Corporation is pleased to announce the release of the new ADT710 Automated Gauge Calibration System, an innovative solution that combines precision pressure control with advanced image recognition technology to fully automate the calibration of dial and digital pressure gauges.

Designed to improve efficiency, consistency, and throughput in demanding calibration environments, the ADT710 eliminates the need for manual gauge readings while delivering fast, repeatable, and highly accurate calibration results. The system features a high-resolution 50-megapixel HD camera with automatic zoom and focus, advanced AMetis recognition technology, a responsive 5-inch TFT touchscreen interface, and fully automated pressure discharge functionality.

When paired with Additel pressure controllers and ACal software, the ADT710 provides a complete hands-free calibration solution that significantly reduces labor requirements and improves workflow efficiency in metrology laboratories, calibration service centers, and industrial instrument workshops.

The ADT710 is capable of calibrating pressure instruments from vacuum to 15,000 psi (100 MPa) using either gas or liquid media. The system delivers reading precision better than 0.1 division and maintains accurate measurements even under varying lighting conditions. Automatic camera positioning and focus ensure reliable image capture and consistent results across a wide range of gauge types and sizes.

Additional features include integrated barcode and QR code recognition for streamlined asset identification and a built-in tapper for analog gauges. Other features include hand-tight quick pressure connections and WLAN/Ethernet communication capabilities, allowing flexible integration into modern automated calibration workflows. For high-volume calibration environments, up to 10 ADT710 systems can be daisy-chained together using Additel's ACal software to create a scalable automated calibration line capable of significantly increasing throughput and efficiency.

For more information about the ADT710 Automated Gauge Calibration System, please visit www.additel.com or contact your local Additel representative.

Mahr Inc. Introduces MarSurf3D MS Optical Metrology Platform

PROVIDENCE, RI – June 24, 2026 – Mahr Inc., a leading provider of dimensional metrology solutions, announced the launch of its MarSurf3D MS optical metrology platform, featuring a multisensor measuring head designed to deliver flexibility and modularity with precision. The new 3D optical platform enables manufacturers to easily customize and configure a single measurement system that meets their specific application requirements, eliminating the need to switch between instruments.

The MarSurf3D MS is capable of real-time measurements down to the sub-nanometer range with a flexible multisensor measuring head that combines three distinct area-based measuring technologies:

LED Confocal: The patented multi-pinhole technology ensures ultra-fast image capture with the highest signal quality, delivering maximum repeatability down to the nanometer range on nearly any surface condition.

White Light Interferometry: Offers vertical resolution in the sub-nanometer range regardless of magnification, making it ideal for measurement of ultra-precise step heights and very low roughness surfaces.

Focus Variation with Active Lighting: Developed specifically for measuring the geometry of large, rough surfaces, allowing steeply inclined surfaces (up to 86°) and large vertical ranges to be captured in a single measurement.

MarSurf3D MS technology is available with a wide variety of axes off-the-shelf. Built for versatility, this powerful multifunctional tool can be used in laboratories, quality assurance environments, or directly on the production floor. It addresses a broad spectrum of manufacturing applications, including structured, rough, and smooth surfaces, steep flanks, layer thickness, and large height measuring ranges.

Key features of the MarSurf3D MS platform include:

Automation-Ready: Measurements can be fully automated to increase throughput and reduce operator error.

Wide range of workpieces: Material-independent measurement of any geometries and surface characteristics regardless of whether they are reflective, absorbent, opaque, or transparent.

Intuitive operation: Simple, user-guided interface with automatic modes for all significant measuring parameters, including the use of measurement protocols for known surfaces.

Optimal data quality: Excellent precision, accuracy, repeatability, reproducibility, and documentation to ensure traceability and auditability.

"Historically, quality assurance and manufacturing operations had to compromise on surface inspection or invest in multiple costly, single-purpose instruments to handle different materials," said Dr Christian Wichern, PhD, Product Manager at Mahr Inc. "The MarSurf3D MS platform changes that by combining three distinct, high-performance optical technologies into a multisensor system that brings speed, flexibility, and repeatability to 3D surface measurement."

For more information, visit www.mahr.com

Vitrek Introduces Intelligent Cable Test Automation Solution

Lockport, IL—May 28, 2026 — Vitrek, a U.S.-based manufacturer of precision electrical safety and high-voltage test equipment, announced an advanced cable testing solution that combines the power of the **Vitrek V10X Hipot Tester** with the scalability of the **Vitrek 964i High Voltage Switching System** to help manufacturers automate high-voltage cable validation, improve throughput, and strengthen quality assurance.

As cable assemblies become more complex across EV platforms, aerospace systems, medical devices, industrial automation, and defense electronics, manufacturers need faster ways to validate insulation integrity, dielectric withstand performance, continuity, and wiring accuracy—without increasing operator burden.

The combined V10X + 964i platform transforms traditional point-by-point cable testing into an intelligent automated workflow. Key capabilities include:

- Automated routing across multi-conductor cable assemblies
- High-voltage AC/DC hipot testing & leakage current detection with high sensitivity
- Reduced manual fixturing and setup time & barcode-enabled operator workflows
- Built-in PDF/CSV reporting for digital traceability
- Scalable architecture for complex harnesses and production growth

The V10X delivers up to 30 kV AC output with modern touchscreen control, automation interfaces, and integrated reporting, while the 964i expands testing across multiple conductors and test points through configurable high-voltage switching cards.

"Cable manufacturers are under pressure to increase output while proving every assembly meets higher safety and reliability expectations," said Chad Clark, VP Sales at Vitrek. "This solution helps customers move beyond slow manual testing into fully automated, data-driven validation."

The platform is ideal for manufacturers of:

- EV charging cables and battery harnesses
- Aerospace wire bundles & medical cables and patient assemblies
- Industrial machine wiring harnesses & defense and ruggedized interconnect systems

For more information, visit Vitrek.com.

Hard Work Pays in the End

Michael L. Schwartz
Cal Lab Solutions, Inc.

I remember calibrating my first PXI instrument and wondering what I'd done to make the calibration gods so mad at me. At the time, I didn't realize it was a blessing in disguise.

PXI and PXIe instruments are fundamentally different from the standalone benchtop gear most technicians spend their career working on. You can't just plug them in, press a few buttons on the front panel, and take a measurement. They require a host computer, a carefully configured driver environment, and software that can interface directly to vendor-specific driver libraries. For a calibration technician, the job quickly shifts from traditional metrology to something that feels more like IT system support.

The temptation to bypass PXI instruments is tied to how long it takes to get the software working. When the technical overhead of troubleshooting the software overshadows the actual calibration task, it can feel like you are just spinning your wheels. Time is better spent calibrating instruments that just work.

IT takes a different skill set to learn how to calibrate PXI instruments, a skill set well worth the time and effort it takes to develop. Being a great electrical calibration technician without skills in modular instruments limits your overall career, because modular instruments are here to stay. And because this is an "Automation Corner" article, knowing how to calibrate PXI instruments and interface with them is a skill you must have in your toolbox.

Unlike traditional benchtop instruments, PXI instruments don't have buttons or knobs. They only talk computer! Sometimes you will get lucky with a unit that has a text/SCPI interface. For the vast majority of PXI instruments, you will have to interface with the hardware using API functions—directly through dynamic libraries. Instead of text commands, you will have to make function calls and pass parameters with software that knows how to communicate with the supplied drivers.

But if you are like me, you want to make your automation easy to understand and easy to support. So how I approached this problem back in 2014 was to create a text interface to the function calls.Visit: https://www.callabsolutions.com/calibrating-a-uut-on-a-remote-computer-using-fluke-metcal/

Our approach is built on a layered architecture that separates the metrology service bus, the measurement process driver, and a command processor. This processor translates high-level text commands into the specific function calls the hardware requires.

By wrapping complex PXI and PXIe systems in this network-agnostic interface, we eliminate the 'struggle' of hardware complexity. Even a multi-slot card in a remote chassis behaves as if it is sitting right on your bench, turning a complex integration into a routine task. This is the foundation of Metrology.NET and the core of Cal Lab Solutions' scalable automation model.

Building this model was a lot of work. It took a lot of revisions to get it right. Communicating with difficult instruments gave birth to Metrology.NET. It was the very first thing we did with the software that eventually became Metrology.NET.

Yes, it was hard work, but well worth it! Because I got a sole-source justification order from the DoD. They asked, "Who do you know who competes with Cal Lab Solutions?" "Who else in the United States can write PXI and PXIe automation?" My first thought was nobody. But then I thought about who competes with Cal Lab Solutions in general.

Then I opened up Google's Gemini and asked the same question. Of those calibration software companies that write automation for benchtop equipment, none of them write custom automation software for PXI and PXIe. None of them have tackled the difficulty of software-based instruments. Most of them haven't even tackled ISO/IEC 17025 uncertainties.

So, if you ask me, Hard Work Pays Off. It led to the creation of a whole new calibration software solution.