Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Introduction to basic uncertainty concepts

Gang Li, Volker Ebert

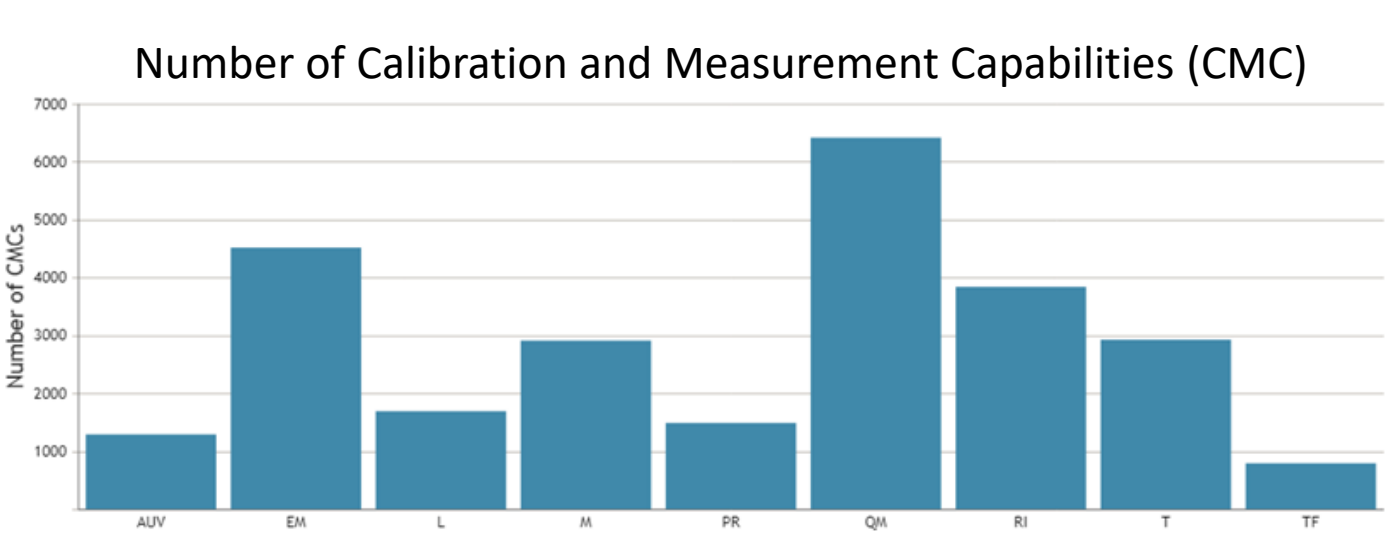
PTB Braunschweig

A man with **one thermometer** knows what temperature it is; A man with **three thermometers** is never quite sure.

We love comparisons

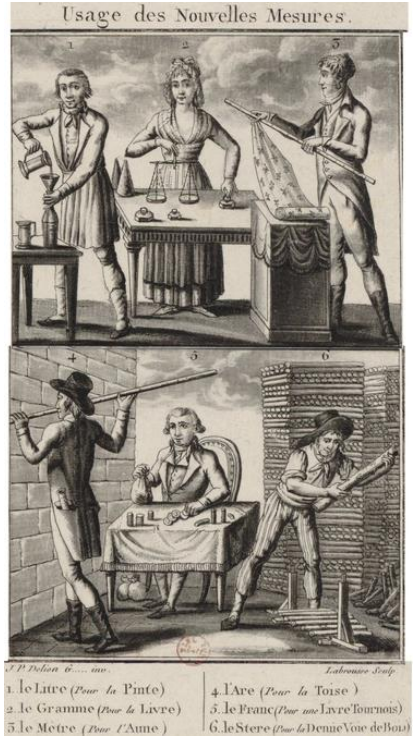
- **Key** Comparisons: Transmitting Correct Measures All Around the World

Blind comparisons



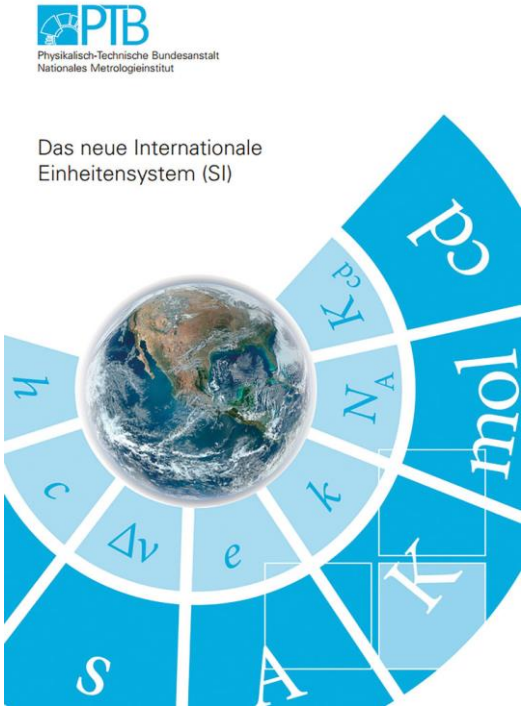
"Make use of the metre"

The new International System of Units (SI)



Woodcut dated **1800** illustrating the new decimal units which became the legal norm across all France on 4 November 1800

Historical international prototype of the metre, made of an alloy of platinum and iridium, that was the standard from **1889 to 1960**



November 2018

The new Kelvin – combining different methods

- Acoustic thermometry
- DCGT(dielectric-constant gas thermometer)
- JNT(Johnson Noise Thermometry) measurements
- Doppler thermometry

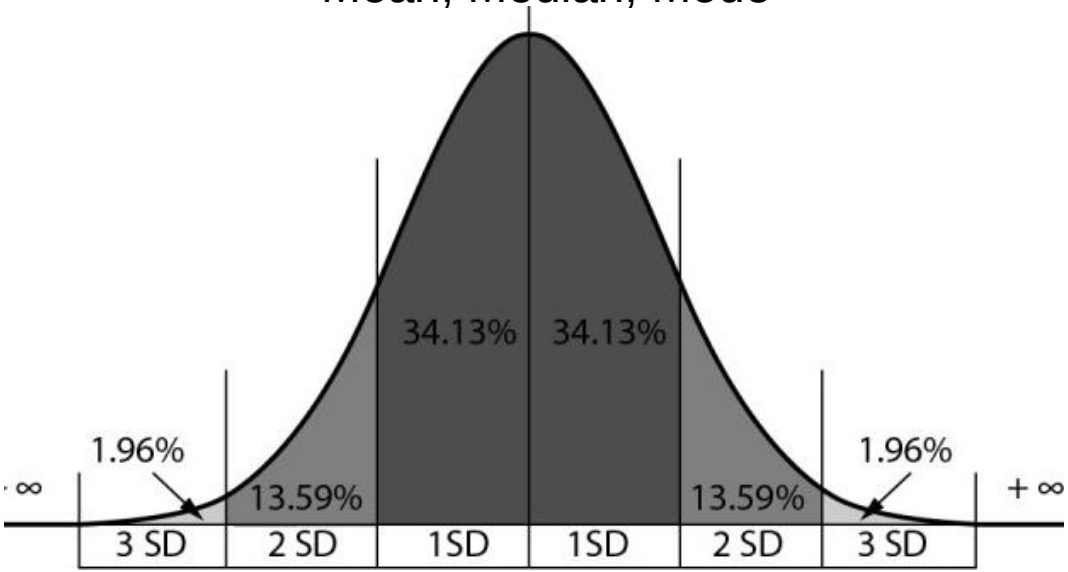
AT, NIST

DCGT, PTB

The Boltzmann constant kB in a revised SI is 1.380649 x 10^{-23} J K^{-1}.

A man with one thermometer **knows** what temperature it is; A man with three thermometers is **never quite sure**.

How confident we are?



The normal Probability Distribution Function (PDF)

A. Coskun and W P. Oosterhuis

PDF: Relationship between the outcome of an event and its frequency of occurrence.

Confidence statement:
level of confidence 95%,
coverage factor k=2,
2σ

Normal distribution is most commonly used for evaluating Type A data:
Data from experimental testing, such as repeatability, reproducibility, and stability testing

Nature of uncertainty

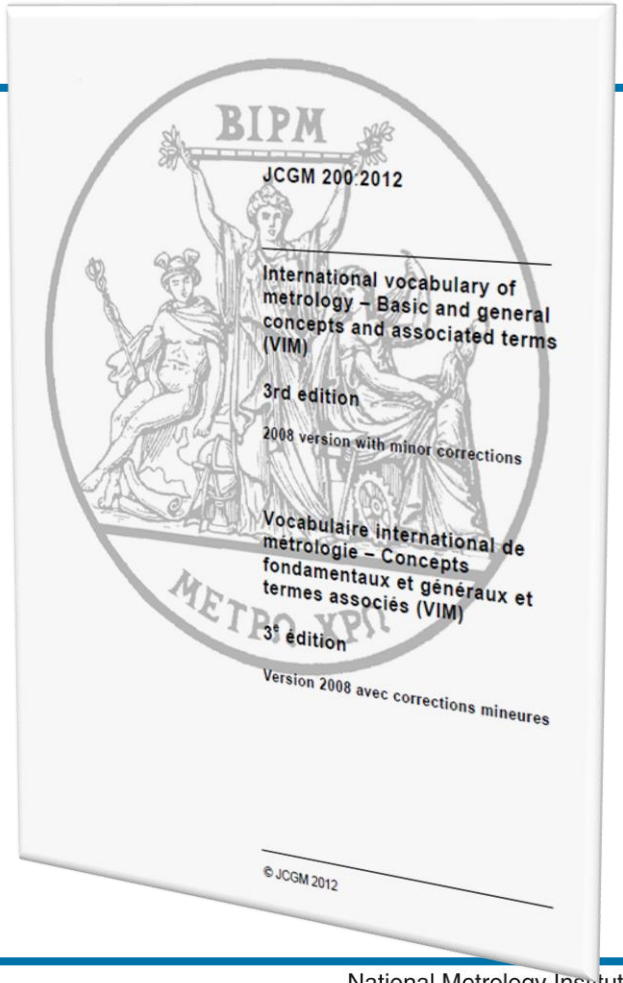
- The uncertainty of the result of a measurement reflects the lack of exact knowledge of the value of the measurand
- Uncertainty arising from
  - Random effects (Type A)
  - Imperfect correction of the result for systematic effects(Type B)
- <Uncertainty> is not <error>!

The “VIM“

- JCGM 200:2012
- International Vocabulary of Metrology – Basic and general concepts and associated terms (VIM)
- This is important because it define the terms that pretty much unique to metrology and they mean exactly

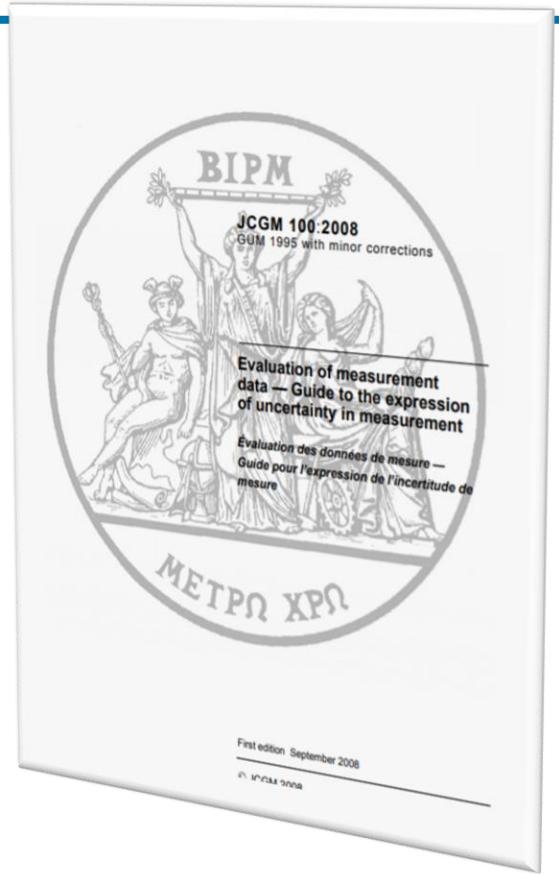
2.28
Type A evaluation of measurement uncertainty
Type A evaluation

evaluation of a component of **measurement uncertainty** by a statistical analysis of **measured quantity values** obtained under defined measurement conditions



The “GUM“

- JCGM 100:2008
- Evaluation of measurement data — Guide to the expression of uncertainty in measurement
  - ✓ Evaluating standard uncertainty
  - ✓ Determining combined standard uncertainty
  - ✓ Determining expanded uncertainty
  - ✓ Reporting uncertainty



Free resources from the BIPM website

Guides in Metrology

Published by the JCGM

Bureau International des Poids et Mesures

GUM: Guide to the Expression of Uncertainty in Measurement

- JCGM 100:2008(E) – in English
  Evaluation of measurement data
- JCGM 100:2008(F) – in French
  Évaluation des données de mesure
- JCGM 101:2008
  Supplement 1 – Propagation of distributions using a Monte Carlo method
- JCGM 102:2011
  Supplement 2 – Extension to any number of output quantities
- JCGM 104:2009
  An introduction to the "GUM" and related documents
- JCGM 106:2012
  Evaluation of measurement data – The role of measurement uncertainty in conformity assessment
- JCGM GUM-6:2020
  Guide to the expression of uncertainty in measurement — Part 6: Developing and using measurement models

www.bipm.org/en/committees/jc/jcgm

Joint Committee for Guides in Metrology (JCGM)

"Maintaining and promoting the Guide to the Expression of Uncertainty in Measurement and the International Vocabulary of Metrology"

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- International Union of Pure and Applied Chemistry → IUPAC
- International Union of Pure and Applied Physics → IUPAP

Who requires it?

- Accreditation bodies
- JCGM 100:2008
- ISO/ICE 17025: 2017 standard
- ILAC P14