



National
Metrology
Institute



“Metrology”

31 May 2024

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Chief Metrologist Flow



This PowerPoint presentation is for educational purposes only!

Agenda

1	VSL National Metrology Institute and Erik Smits.
2	Did you experience this?
3	Metrology and SI.
4	BIPM, EURAMET, NMIs and DIs.
5	Make measurement possible.
6	What to remember?



VSL tasks, responsibilities and services

■ Research and Development

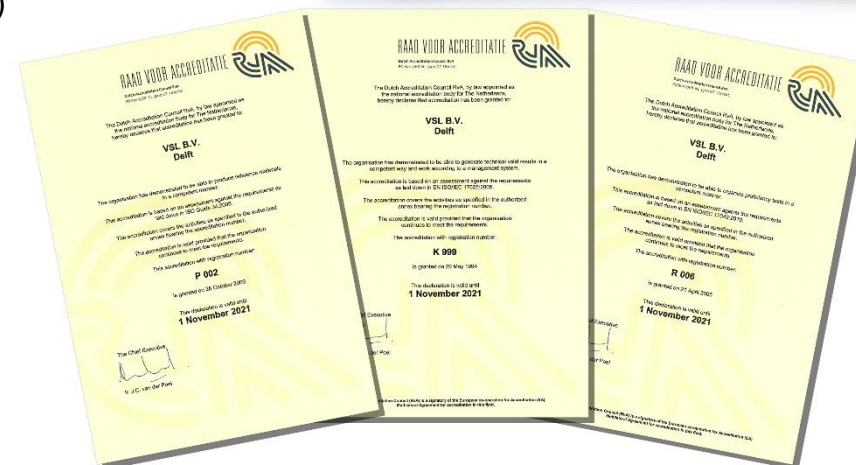
- Development and maintenance national measurement standards
- International traceability assurance
- Research in metrology and measurement systems

■ Calibration and Reference materials

- Calibrations of instruments (CIPM MRA and RvA K999)
- Reference materials (CIPM MRA and RvA P002)
- Proficiency testing / comparisons (RvA R006)

■ Customized Metrology

- Consultancy
- R&D Contracts
- International projects, training



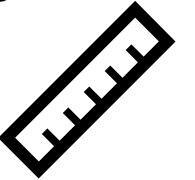
Erik Smits

- Hometown Dordrecht in the Netherlands
- 31+ years in metrology with VSL
- Chief Metrologist
- EURAMET TC Flow chairperson
- Auditor for accredited companies according to ISO/IEC17025 and ISO/IEC17020 / Peer reviewer



Did you experience this?

- I filled up my car with petrol, and it feels like the volume displayed on the fuel dispenser is more than I expected as the dial in my car was not in the red zone yet. Is this volume correct?
- I measured the length of a curtain I needed at home for my windows, I bought the curtain to that exact length, and it does not fit. How can that be?
- This morning on the news they said it is +5 °C outside but it feels like it is freezing!
- I used a weighing scale to see if I lost weight, but it is reading more than I expected. For sure this weighing scale is wrong!



The definition for “Metrology”

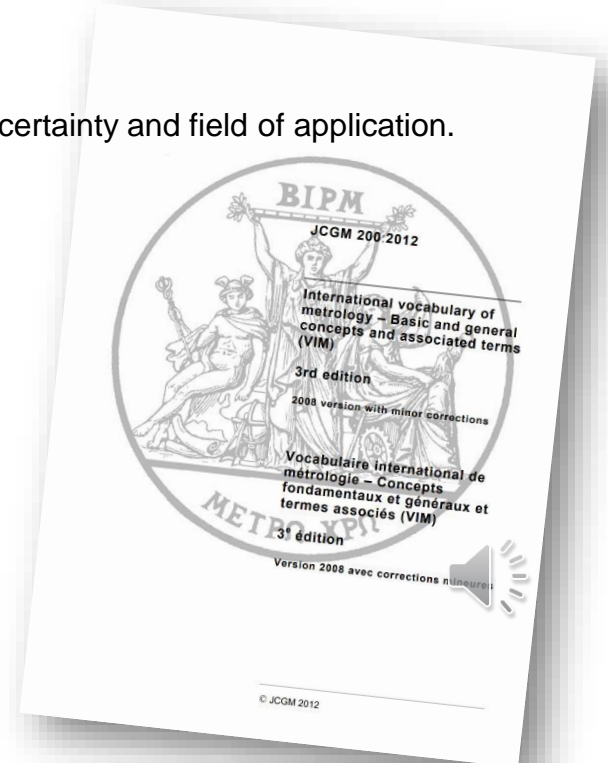
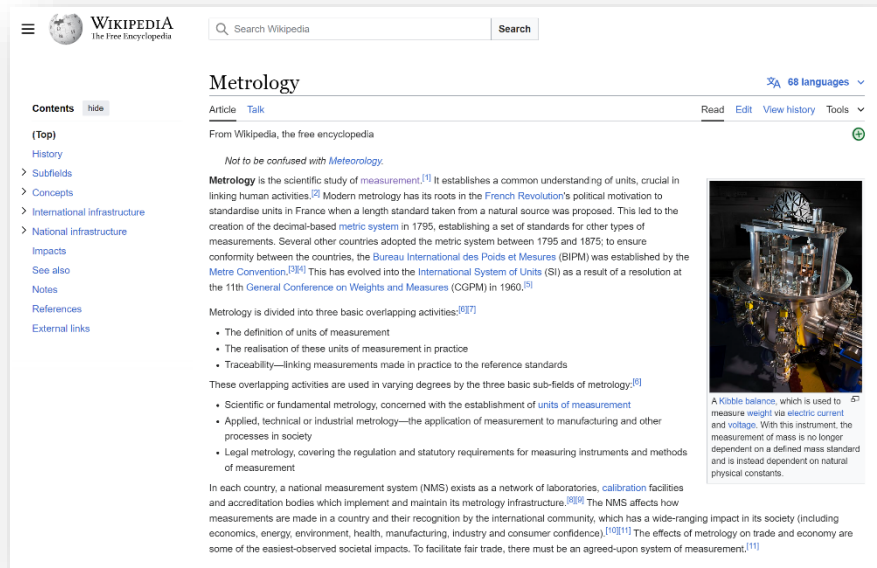
- <https://en.wikipedia.org/wiki/Metrology>

Not to be confused with Meteorology!

Metrology is the scientific study of measurement.

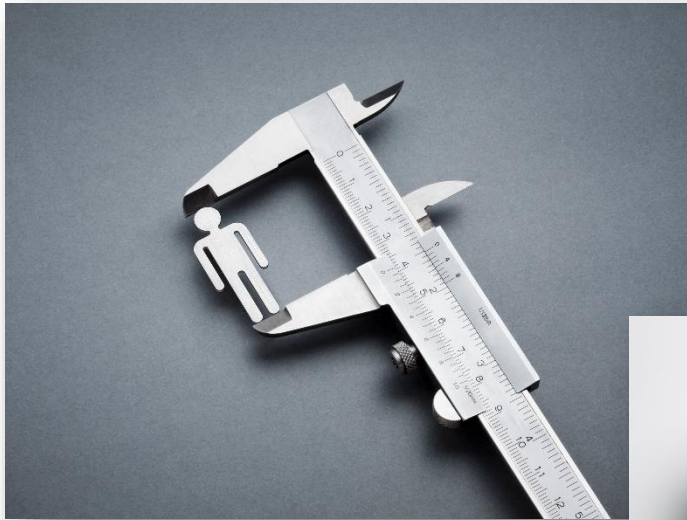
- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(2.2) Science of measurement and its application

NOTE Metrology includes all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application.



Measurement

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(2.1) Process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity



Quantity

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(1.1) Property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

NOTE 2: A **reference** can be a measurement unit, a measurement procedure, a reference material, or a combination of such.

1 kg

0.12 m

100 km/h

9.822 s

0.5 mL



Measurement unit

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(1.9) real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number

NOTE 1: Measurement units are designated by conventionally assigned names and symbols.

kg

m

lb

s

bar



Base unit

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(1.10) measurement unit that is adopted by convention for a base quantity

NOTE 1: In each coherent system of units, there is only one base unit for each base quantity

SI

USC

Imperial



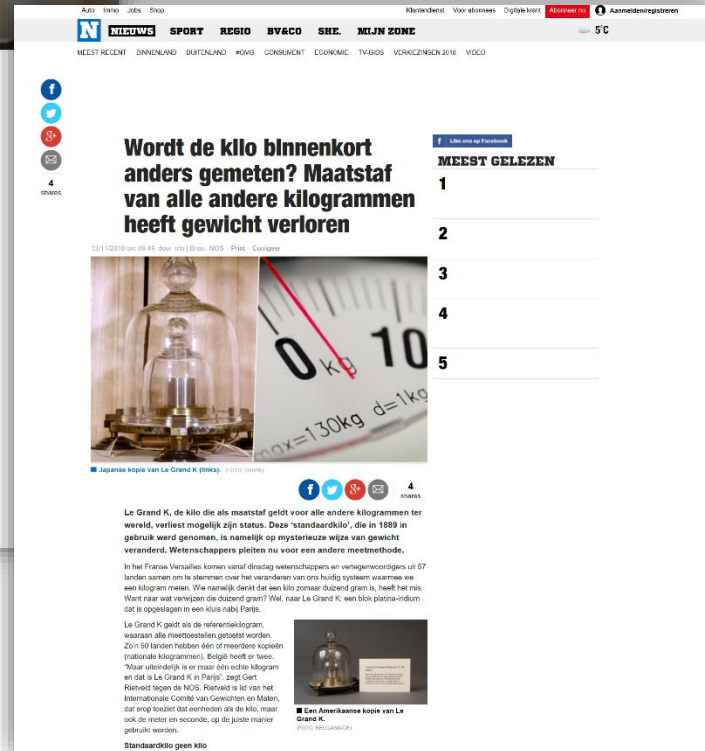
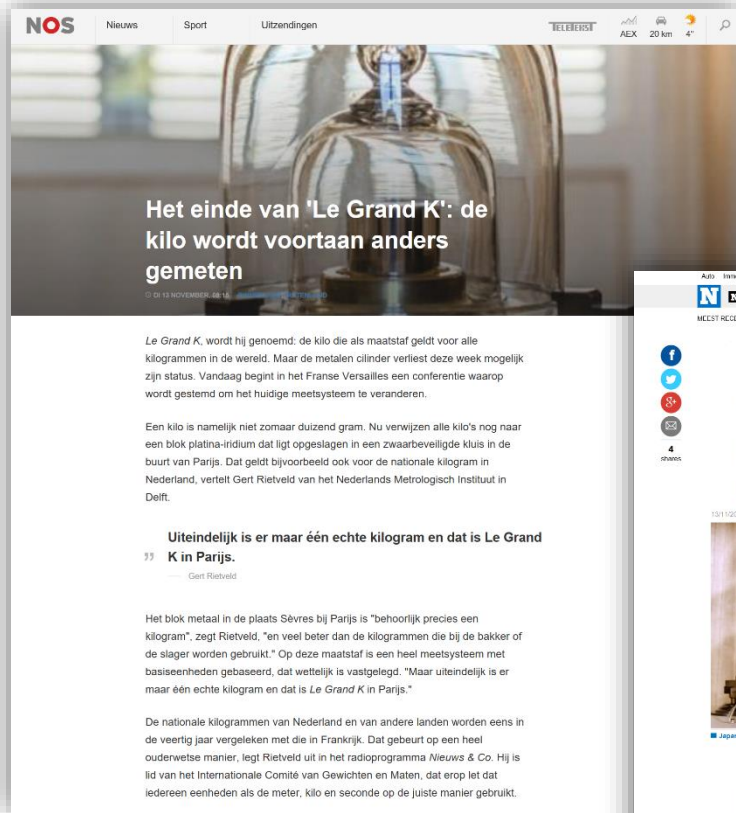
International System of Units (SI)

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(1.16) system of units, based on the International System of Quantities, their names and symbols, including a series of prefixes and their names and symbols, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)

Base quantity (name)	Base unit (name)	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electrical current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd



The International System of Units



Kilogram (kg)

The kilogram is the SI unit of mass

The kilogram is defined by taking the fixed numerical value of the Planck constant h to be [6.626 070 15](#) $\times 10^{-34}$ when expressed in the unit J s, which is equal to $\text{kg m}^2 \text{s}^{-1}$, where the metre and the second are defined in terms of c and $\Delta\nu$.



Metre (m)

The metre is the SI unit of length

The metre is defined by taking the fixed numerical value of the speed of light in vacuum c to be [299 792 458](#) when expressed in the unit m s^{-1} , where the second is defined in terms of the caesium frequency $\Delta\nu$.



Second (s)

The second is the SI unit of time

The second is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be [9 192 631 770](#) when expressed in the unit Hz, which is equal to s^{-1} .



Ampere (A)

The ampere is the SI unit of electric current

The ampere is defined by taking the fixed numerical value of the elementary charge e to be 1.602 176 634 $\times 10^{-19}$ when expressed in coulombs, which is equal to A s, where the second is defined in terms of $\Delta\nu$.



Kelvin (K)

The kelvin is the SI unit of thermodynamic temperature

The kelvin is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380 649 $\times 10^{-23}$ when expressed in the unit J K^{-1} , which is equal to $\text{kg m}^2 \text{s}^{-2} \text{K}^{-1}$, where the kilogram, metre and second are defined in terms of h , c and $\Delta\nu$.



Mole (mol)

The mole is the SI unit of amount of substance

One mole contains exactly 6.022 140 76 $\times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A , when expressed in the unit mol^{-1} and is called the Avogadro number.



Candela (cd)

The candela is the SI unit of luminous intensity in a given direction

The candela is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd} , to be 683 when expressed in the unit lm W^{-1} , which is equal to cd sr W^{-1} .

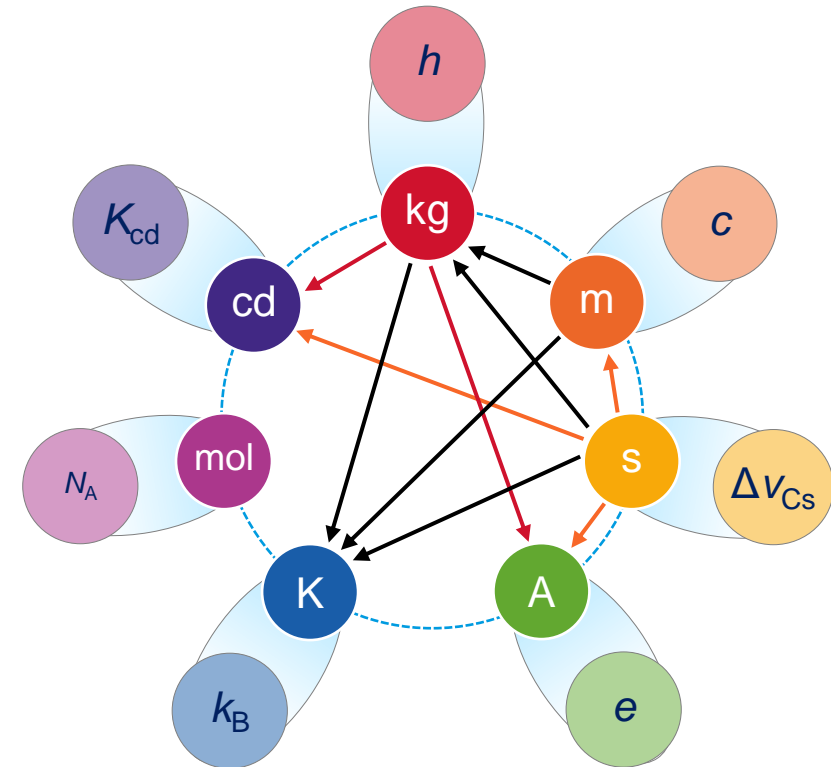


The constants from the SI used for the base units

THE DEFINING CONSTANTS OF THE INTERNATIONAL SYSTEM OF UNITS

Defining constant	Symbol	Numerical value	Unit
hyperfine transition frequency of Cs	$\Delta\nu_{\text{Cs}}$	9 192 631 770	Hz
speed of light in vacuum	c	299 792 458	m s^{-1}
Planck constant*	h	$6.626\,070\,15 \times 10^{-34}$	J Hz^{-1}
elementary charge*	e	$1.602\,176\,634 \times 10^{-19}$	C
Boltzmann constant*	k	$1.380\,649 \times 10^{-23}$	J K^{-1}
Avogadro constant*	N_A	$6.022\,140\,76 \times 10^{23}$	mol^{-1}
luminous efficacy	K_{cd}	683	lm W^{-1}

*These numbers are from the CODATA 2017 special adjustment. They were calculated from data available before the 1st of July 2017.



Acceptance of the the International System of Units



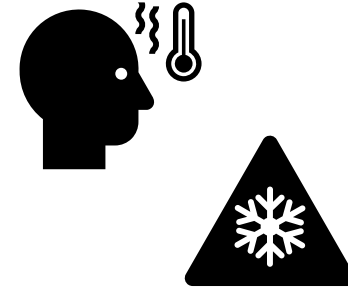
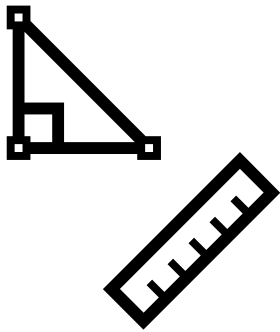
BIPM, OIML, ILAC, and ISO endorse the following recommendations:

- In order to be able to rely on their **international acceptability**, calibrations should be performed
 - in **National Metrology Institutes** which should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB or
 - in laboratories **accredited to ISO/IEC 17025** by accreditation bodies that are signatories to the ILAC Arrangement;
- **measurement uncertainty** should follow the principles established in the GUM;
- the results of the measurements made in accredited laboratories should be **traceable to the SI**;
- NMIs providing metrological traceability for accredited laboratories should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB;
- within the OIML-CS, accreditation should be provided by bodies which are signatories to the ILAC Arrangement and the above policies on metrological traceability to the SI should be followed.

The above principles should be used whenever there is a need to demonstrate metrological traceability for international acceptability.



How do you know when you take a measurement it is correct?



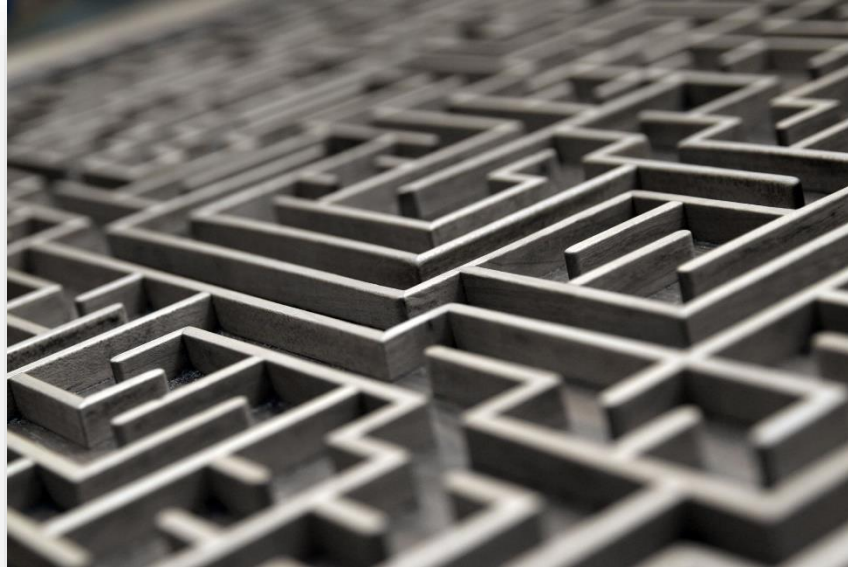
Metrological traceability



Metrological traceability

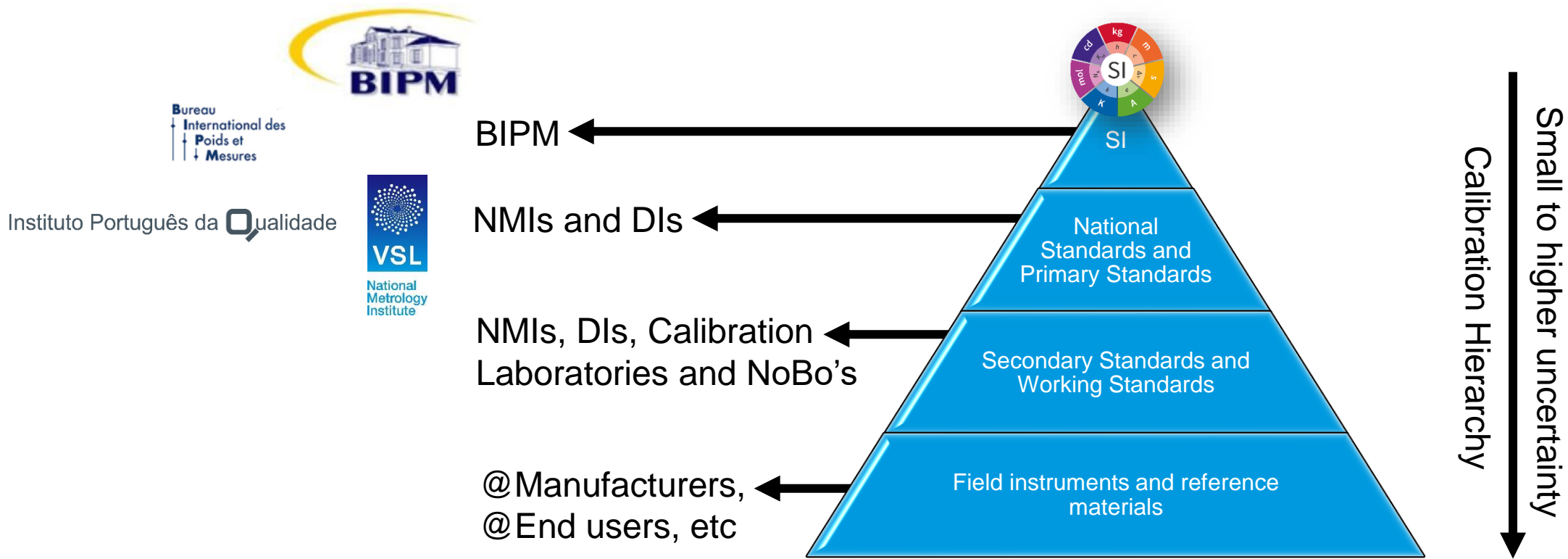
- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms
(2.41) property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

NOTE 2: Metrological traceability requires an established calibration hierarchy.



National Metrology Institutes (such as VSL, IPQ and others)

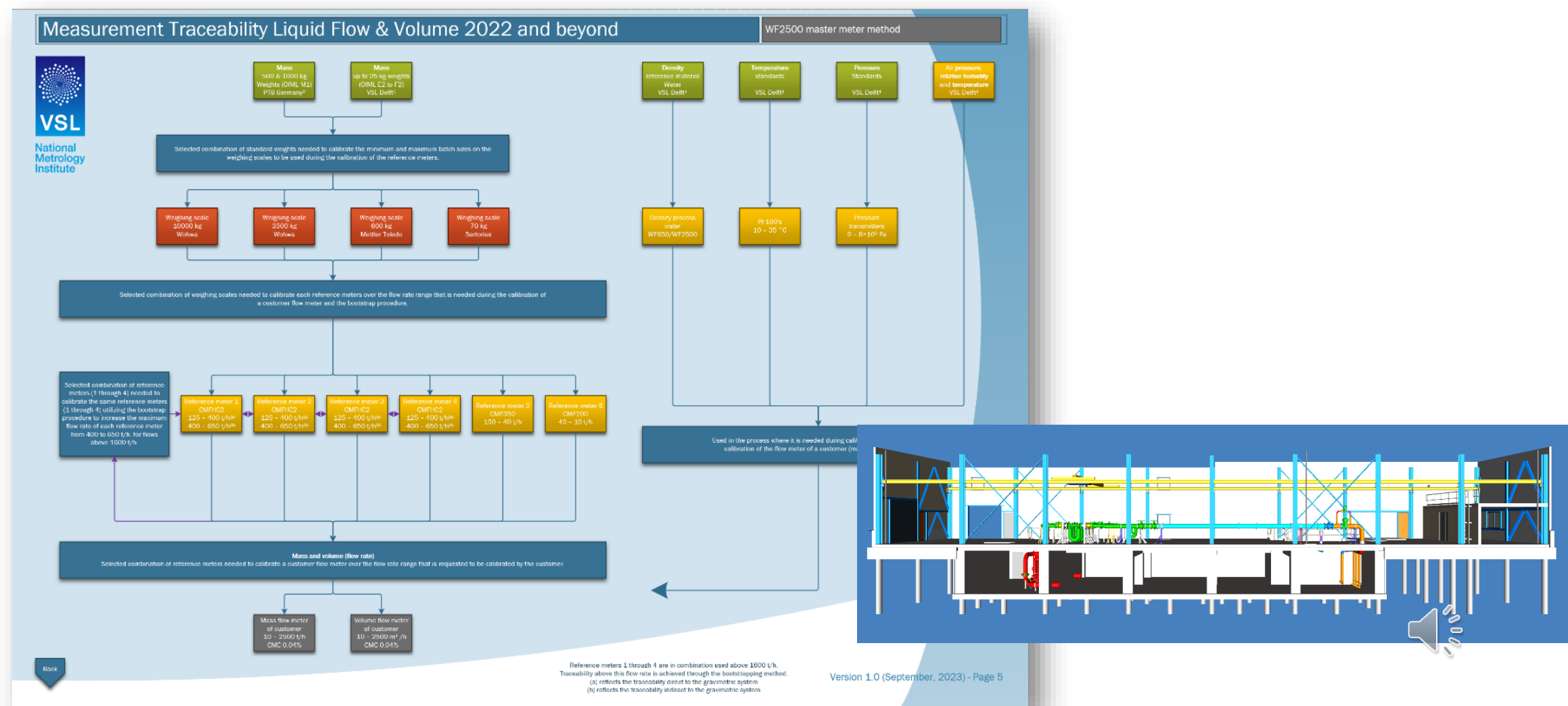
In the top of the metrological pyramid



Metrological traceability requires an established calibration hierarchy



Water flow measurement traceability



Metrology in a circle is not possible



The BIPM is an international organization established by the Metre Convention, through which Member States act together on matters related to measurement science and measurement standards.

Vision

Their vision is to be the world focus for the international system of measurement.

Mission

Their mission is to work with the NMIs of the BIPM's Member States, the **RMOs**, and strategic partners world-wide, and to use our international and impartial status to promote and advance the global comparability of measurements for:

- scientific discovery and innovation;
- industrial manufacturing and international trade;
- improving the quality of life and sustaining the global environment.

Objectives

- To represent the world-wide measurement community;
- To be a centre for scientific and technical collaboration between Member States;
- To be the coordinator of the world-wide measurement system.



EURAMET (RMO for Europe)

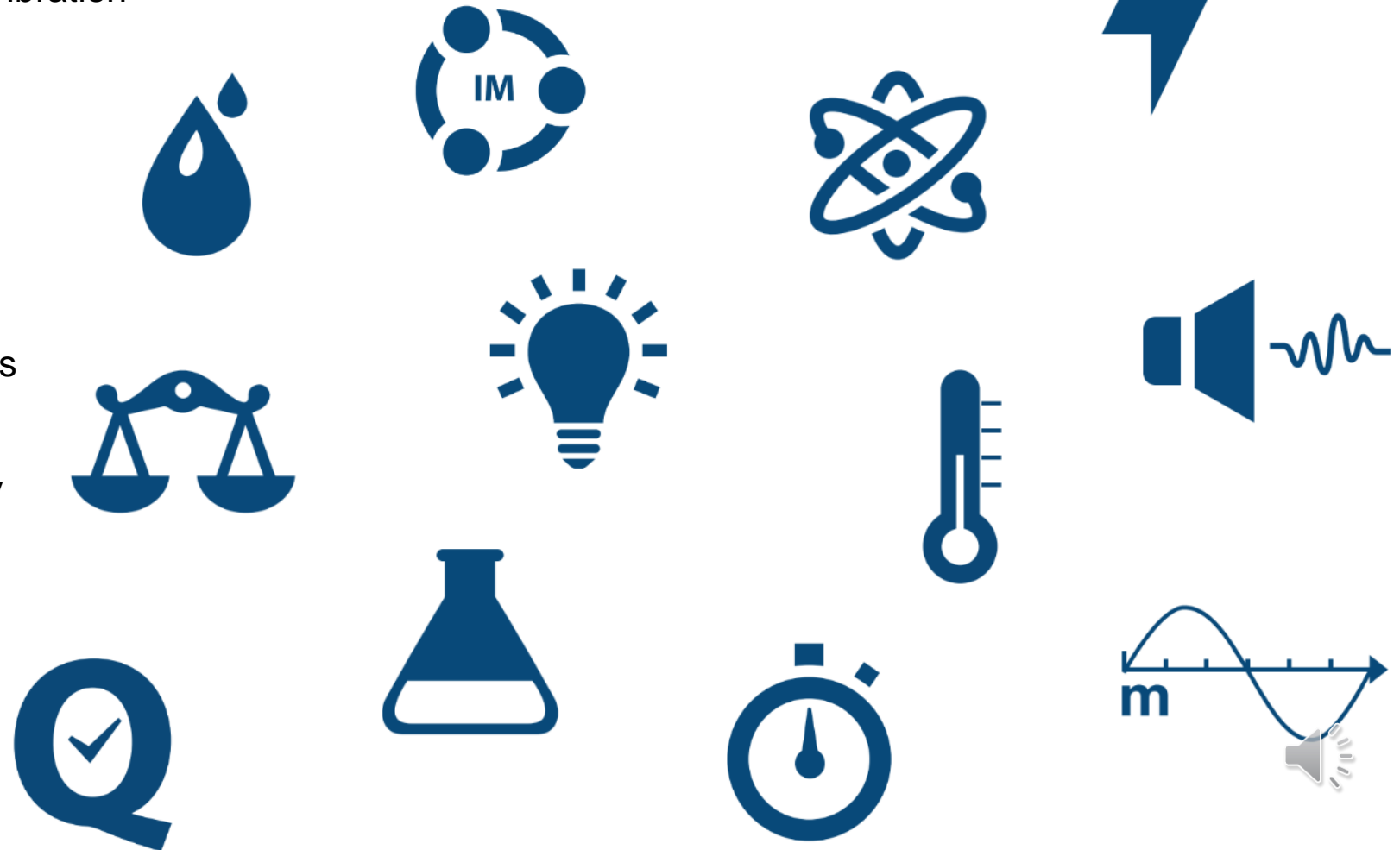
EURAMET is the Regional Metrology Organisation (RMO) of Europe. We coordinate the cooperation of National Metrology Institutes (NMI) and Designated Institutes (DIs) in Europe in fields such as research in metrology, traceability of measurements to the SI units, international recognition of national measurement standards and related Calibration and Measurement Capabilities (CMC). Through Knowledge Transfer and cooperation among our members EURAMET facilitates the development of the national metrology infrastructures.

The Comité International des Poids et Mesures (CIPM) sponsored the creation of a Mutual Recognition Scheme (CIPM MRA) to underpin and formalise technical competence of its signatory National Metrology Institutes and Designated Institutes.



EURAMETs Technical Committees (TCs)

- Acoustics, Ultrasound and Vibration
- Electricity and Magnetism
- Flow
- Interdisciplinary Metrology
- Ionising Radiation
- Length
- Mass and Related Quantities
- Metrology in Chemistry
- Photometry and Radiometry
- Quality
- Thermometry
- Time and Frequency



National Metrology Institutes (NMI) and Designated Institutes (DI)

A National Metrology Institute (NMI) is an organisation responsible for maintaining and developing national primary measurement standards. These standards serve as the foundation for all measurements made within a country. Here are some key points about NMIs:

- Primary Measurement Standards;
- Measurement traceability;
- Role in the National Measurement System;
- International Collaboration (comparing measurement standards and research);
- Support for Innovation and Industry.

Instituto Português da ualidade



Let's go back to the question

I filled up my car with petrol, and it feels like the volume displayed on the fuel dispenser is more than I expected as the dial in my car was not in the red zone yet. Is this volume correct?

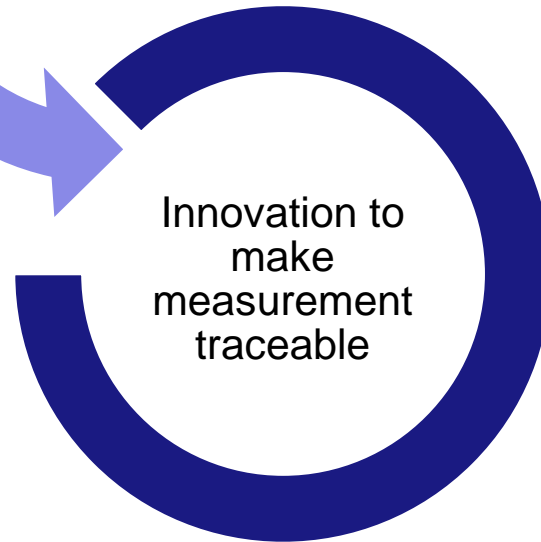
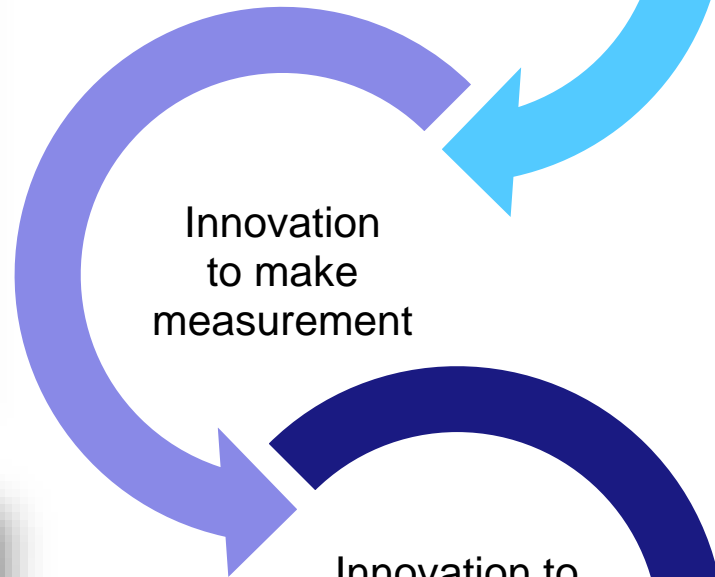
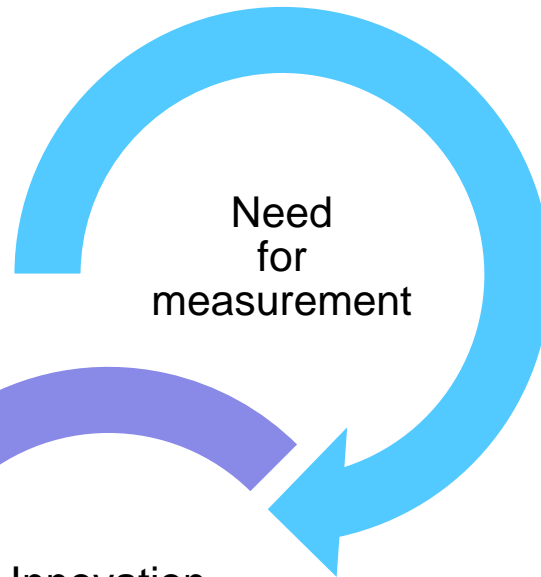
- The answer is: YES, within the tolerances of the local legislation based on international directives.
- Today the tolerance in most countries is $\pm 0.5\%$ of the volume indicated on the fuel dispenser. In the past, it was $\pm 1.0\%$. Over time with research instrumentation to measure petrol and diesel improved.

We are still innovating fuel dispensers for more difficult liquids and gasses to be measured. Think about LNG and H_2 .

In the following example the development for making LNG flow (volume) measurable at cryogenic conditions @ -162 °C.



Make Measurable



Are we done when we can measure something?

We need to ask ourselves the question: What is the measurement uncertainty we can achieve and what does it affect?

- Is this uncertainty good enough to prove/verify measurement instruments that need to operate within tolerances set in written standards and legislation?
- Do we need to update the measurement standards to meet the written standard? (Achieve lower measurement uncertainty? How do we do this?)
- Do we need to feed the found information and measurement methods into written standards or update standards? (Making tolerances smaller or maybe less optimistic in other words realistic.)
- Over time technologies will be developed and NMI's need to keep up to make measurement possible and develop better measurement standards to decrease the measurement uncertainty to make innovations possible.
- Written standards need to be updated when new information and research is available, or at a time when measurement needs to be improved for whatever reason.



What to remember!

- Metrology is the science of measurement and its application;
- Measurements need to be traceable to higher measurement standards (metrology in a circle does not work);
- The measurement uncertainties and accuracies/tolerances need to be known and well specified in any document written and performed measurement;
- Use the vocabulary made by the internal metrology communities in written standards when talking about measurement;
- Do not event the wheel talk to NMIs or RMOs when measurements are needed in your work.
- Make sure measurement is Beyond All Doubt!



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Metrology

