VSL
National Metrology Institute

“Metrology”

31 May 2024

Erik Smits

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?

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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

CIPM MRA

National Metrology Institute

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

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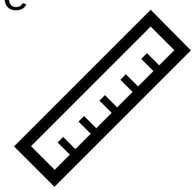
Did you experience this?

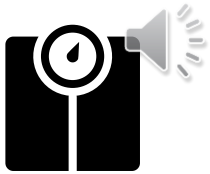
- I filled up my car with petrol, and it feels like the volume displayed on the fuel dispenser is more then I expected as the dial in my car was not in the red zone yet. Is this volume correct?



- 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 then I expected. For sure this weighing scale is wrong!



The definition for “Metrology”

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

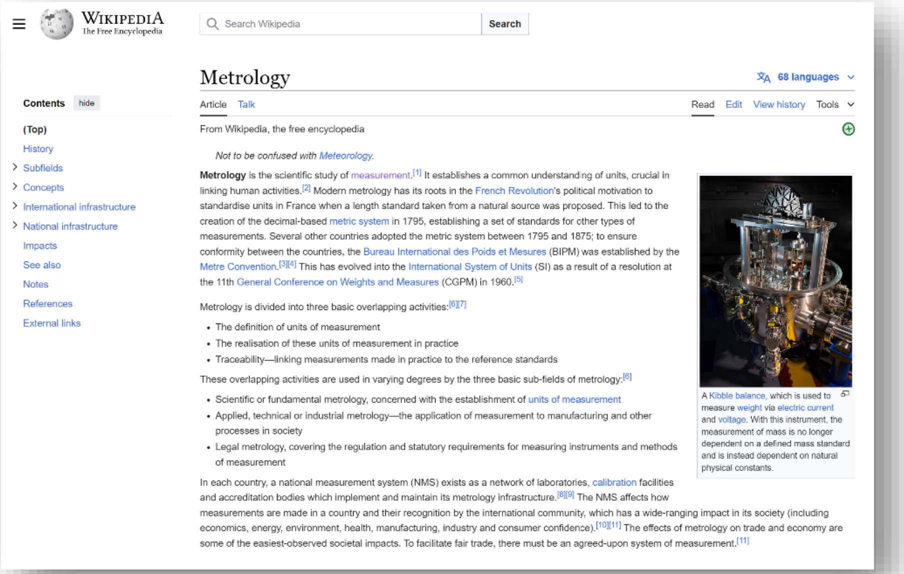
  Not to be confused with Meteorology!

  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.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Metrology

68 languages

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From Wikipedia, the free encyclopedia

Not to be confused with Meteorology.

Metrology is the scientific study of measurement.[1] It establishes a common understanding of units, crucial in linking human activities.[2] Modern metrology has its roots in the French Revolution's political motivation to standardise units in France when a length standard taken from a natural source was proposed. This led to the creation of the decimal-based metric system in 1795, establishing a set of standards for other types of measurements. Several other countries adopted the metric system between 1795 and 1875; to ensure conformity between the countries, the Bureau International des Poids et Mesures (BIPM) was established by the Metre Convention.[3][4] This has evolved into the International System of Units (SI) as a result of a resolution at the 11th General Conference on Weights and Measures (CGPM) in 1960.[5]

Metrology is divided into three basic overlapping activities:[6][7]

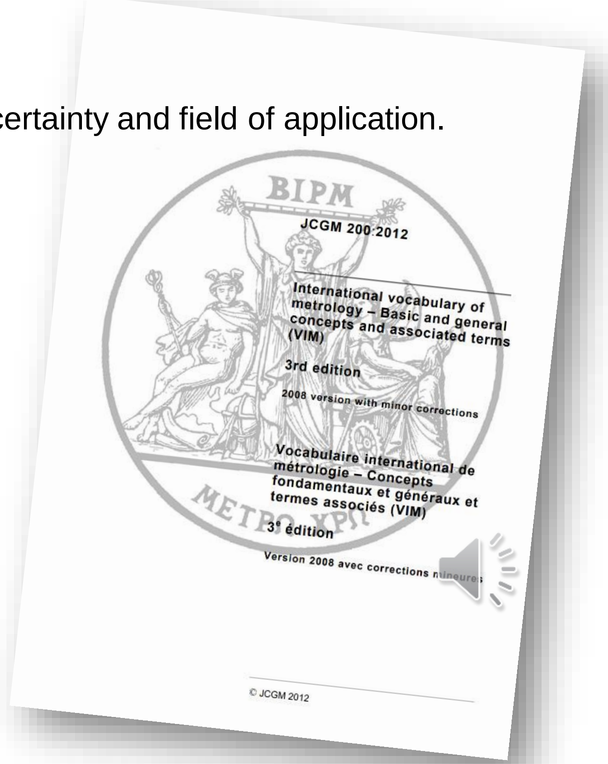
- The definition of units of measurement
- The realisation of these units of measurement in practice
- Traceability—linking measurements made in practice to the reference standards

These overlapping activities are used in varying degrees by the three basic sub-fields of metrology:[6]

- Scientific or fundamental metrology, concerned with the establishment of units of measurement
- Applied, technical or industrial metrology—the application of measurement to manufacturing and other processes in society
- Legal metrology, covering the regulation and statutory requirements for measuring instruments and methods of measurement

In each country, a national measurement system (NMS) exists as a network of laboratories, calibration facilities and accreditation bodies which implement and maintain its metrology infrastructure.[8][9] The NMS affects how measurements are made in a country and their recognition by the international community, which has a wide-ranging impact in its society (including economics, energy, environment, health, manufacturing, industry and consumer confidence).[10][11] The effects of metrology on trade and economy are some of the easiest-observed societal impacts. To facilitate fair trade, there must be an agreed-upon system of measurement.[11]

A Kibble balance, which is used to measure weight via electric current and voltage. With this instrument, the measurement of mass is no longer dependent on a defined mass standard and is instead dependent on natural physical constants.



Measurement

- JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms

  (2.1) Process of experimentally obtaining one or more <u>quantity</u> values that can reasonably be attributed to a quantity

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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.

100 km/h

1 kg

0.12 m

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.

lb

kg

m

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

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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

VSL

The International System of Units


NOS
Nieuws
Sport
Uitzendingen

Het einde van 'Le Grand K': de kilo wordt voortaan anders gemeten

Le Grand K, wordt hij genoemd: de kilo die als maatstaf geldt voor alle kilogrammen in de wereld. Maar de metalen cilinder verliest deze week mogelijk zijn status. Vandaag begint in het Franse Versailles een conferentie waarop wordt gestemd om het huidige meetsysteem te veranderen.

Een kilo is namelijk niet zomaar duizend gram. Nu verwijzen alle kilo's nog naar een blok platina-iridium dat ligt opgeslagen in een zwaarbeveiligde kluis in de buurt van Parijs. Dat geldt bijvoorbeeld ook voor de nationale kilogram in Nederland, vertelt Gert Rietveld van het Nederlands Metrologisch Instituut in Delft.

> **Uiteindelijk is er maar één echte kilogram en dat is Le Grand K in Parijs.**
> — Gert Rietveld

Het blok metaal in de plaats Sèvres bij Parijs is "behoorlijk precies een kilogram", zegt Rietveld, "en veel beter dan de kilogrammen die bij de bakker of de slager worden gebruikt." Op deze maatstaf is een heel meetsysteem met basiseenheden gebaseerd, dat wettelijk is vastgelegd. "Maar uiteindelijk is er maar één echte kilogram en dat is *Le Grand K* in Parijs."

De nationale kilogrammen van Nederland en van andere landen worden eens in de veertig jaar vergeleken met die in Frankrijk. Dat gebeurt op een heel ouderwetse manier, legt Rietveld uit in het radioprogramma *Nieuws & Co*. Hij is lid van het Internationale Comité van Gewichten en Maten, dat erop let dat iedereen eenheden als de meter, kilo en seconde op de juiste manier gebruikt.


SPORT REGIO BV&CO SHE. MIJN ZONE

Wordt de kilo binnenkort anders gemeten? Maatstaf van alle andere kilogrammen heeft gewicht verloren

13/11/2018 om 09:49 door rtn | Bron: NOS · Print · Corrigeer

Japanse kopie van Le Grand K (links).

Le Grand K, de kilo die als maatstaf geldt voor alle andere kilogrammen ter wereld, verliest mogelijk zijn status. Deze 'standaardkilo', die in 1889 in gebruik werd genomen, is namelijk op mysterieuze wijze van gewicht veranderd. Wetenschappers pleiten nu voor een andere meetmethode.

In het Franse Versailles komen vanaf dinsdag wetenschappers en vertegenwoordigers uit 57 landen samen om te stemmen over het veranderen van ons huidig systeem waarmee we een kilogram meten. Wie namelijk denkt dat een kilo zomaar duizend gram is, heeft het mis. Want naar wat verwijzen die duizend gram? Wel, naar Le Grand K: een blok platina-iridium dat is opgeslagen in een kluis nabij Parijs.

Le Grand K geldt als de referentiekilogram, waaraan alle meettoestellen getoetst worden. Zo'n 50 landen hebben één of meerdere kopieën (nationale kilogrammen). België heeft er twee. "Maar uiteindelijk is er maar één echte kilogram en dat is Le Grand K in Parijs", zegt Gert Rietveld tegen de NOS. Rietveld is lid van het Internationale Comité van Gewichten en Maten, dat erop toeziet dat eenheden als de kilo, maar ook de meter en seconde, op de juiste manier gebruikt worden.

Een Amerikaanse kopie van Le Grand K. (FOTO: BELGAIMAGE)

Standaardkilo geen kilo

MEEST GELEZEN
1
2
3
4
5

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 × 10^{-34} when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of c and Δv.

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 Δv.

Second (s)

The second is the SI unit of time

The second is defined by taking the fixed numerical value of the caesium frequency Δv, 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 × 10^{-19} when expressed in coulombs, which is equal to A s, where the second is defined in terms of Δv.

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 × $10^{-23}$when expressed in the unit J K^{-1}, which is equal to kg m2s^{-2} K^{-1}, where the kilogram, metre and second are defined in terms of h, c and Δv.

Mole (mol)

The mole is the SI unit of amount of substance

One mole contains exactly 6.022 140 76 × 10^{23} elementary entities. This number is the fixed numerical value of the Avogadro constant, NA, 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}.

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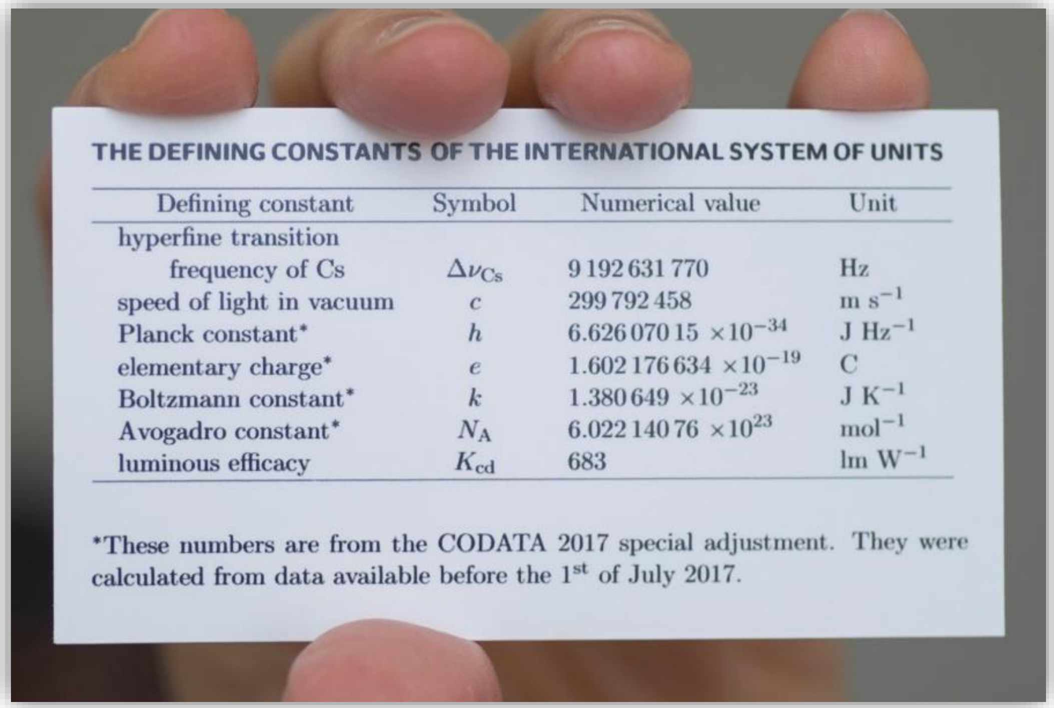
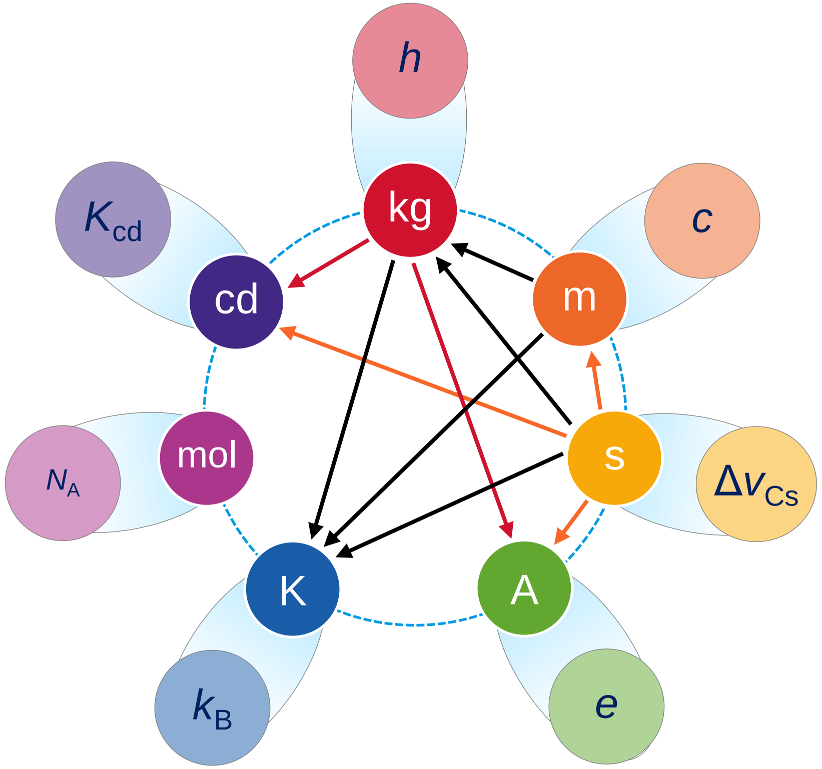
The constants from the SI used for the base units



THE DEFINING CONSTANTS OF THE INTERNATIONAL SYSTEM OF UNITS

Defining constant	Symbol	Numerical value	Unit
hyperfine transition frequency of Cs	$\Delta\nu_{Cs}$	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.



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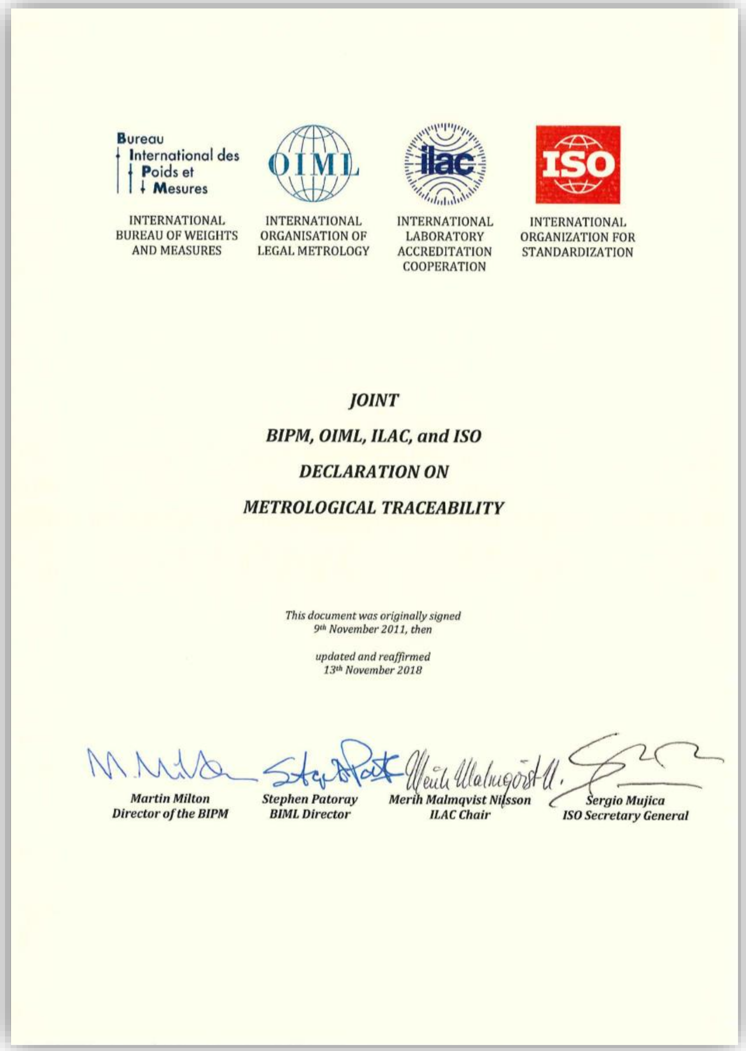
Acceptance of the the International System of Units



Bureau International des Poids et Mesures

INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES

INTERNATIONAL ORGANISATION OF LEGAL METROLOGY

INTERNATIONAL LABORATORY ACCREDITATION COOPERATION

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

JOINT

BIPM, OIML, ILAC, and ISO

DECLARATION ON

METROLOGICAL TRACEABILITY

This document was originally signed 9th November 2011, then

updated and reaffirmed 13th November 2018

Martin Milton, Director of the BIPM

Stephen Patoray, BIML Director

Merih Malmqvist Nilsson, ILAC Chair

Sergio Mujica, ISO Secretary General

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.

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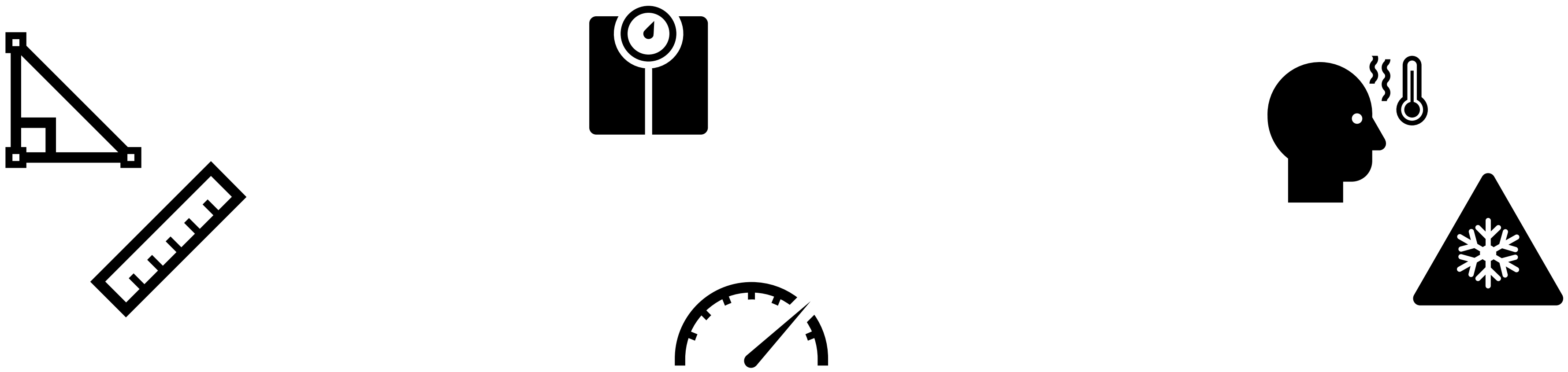
How do you know when you take a measurement it is correct?



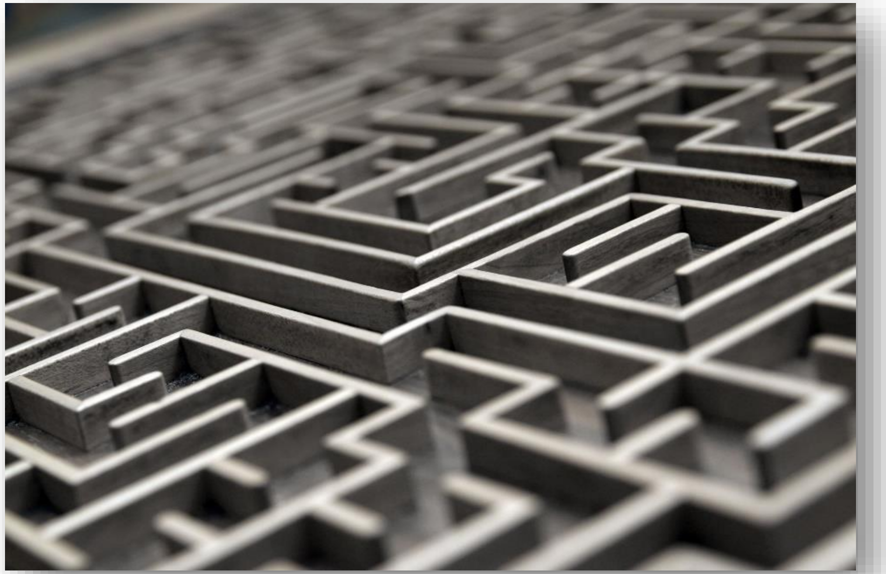
Metrological traceability

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**.



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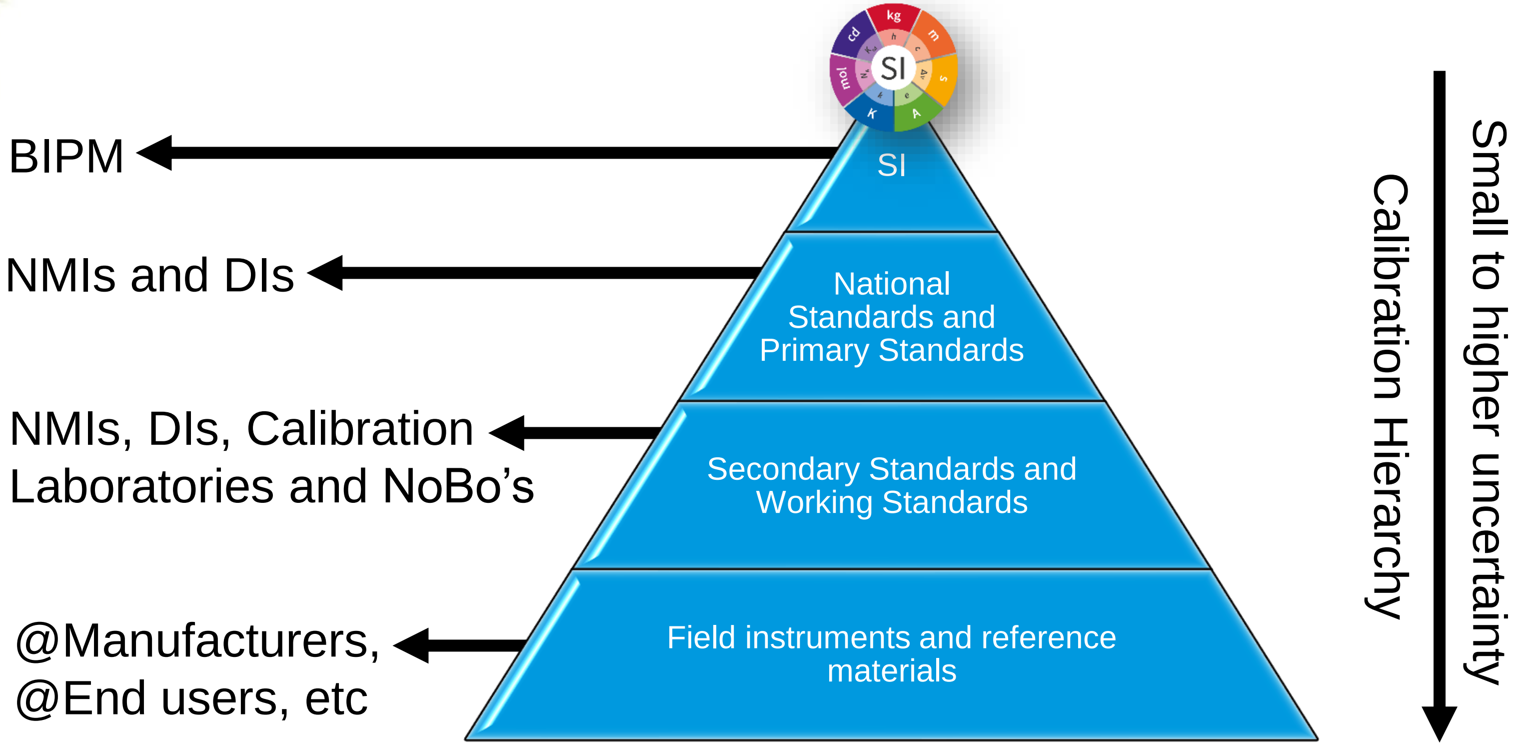
National Metrology Institutes (such as VSL, IPQ and others)

In the top of the metrological pyramid

Bureau International des Poids et Mesures

Instituto Português da Qualidade

National Metrology Institute



Metrological traceability requires an established calibration hierarchy

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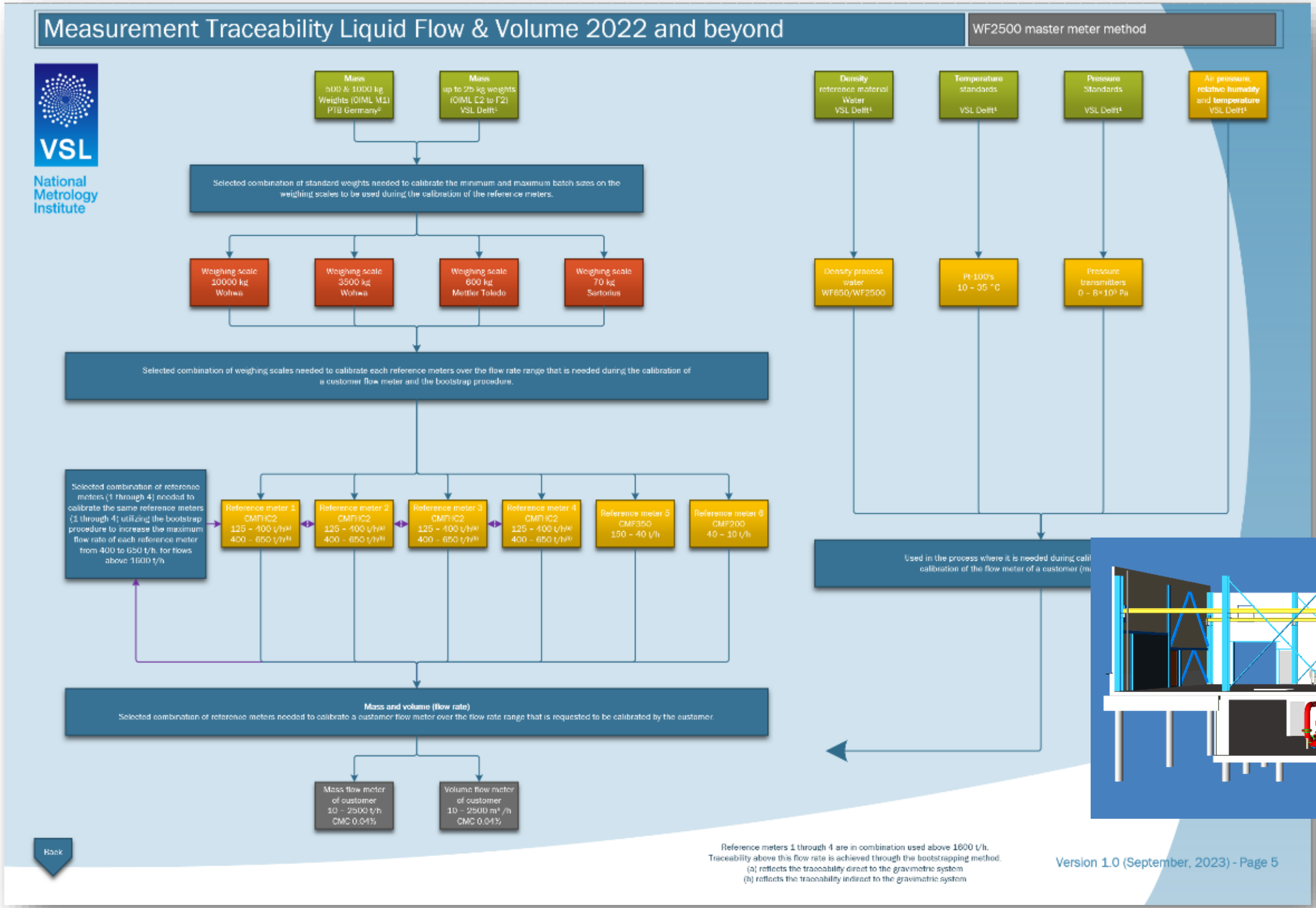
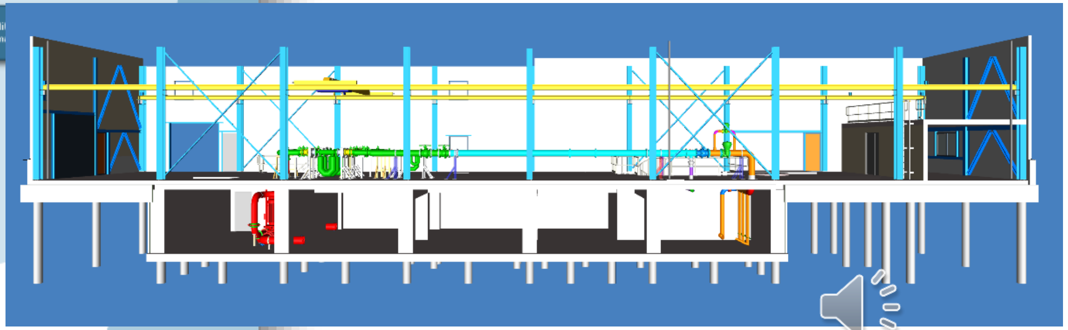
Water flow measurement traceability





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Zanzibar effect

Metrology in a circle is not possible

Drawings generated with AI (Adobe Firefly)

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BIPM

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.

https://www.bipm.org/en/-/mission-role-objectives

EURAMET (RMO for Europe)

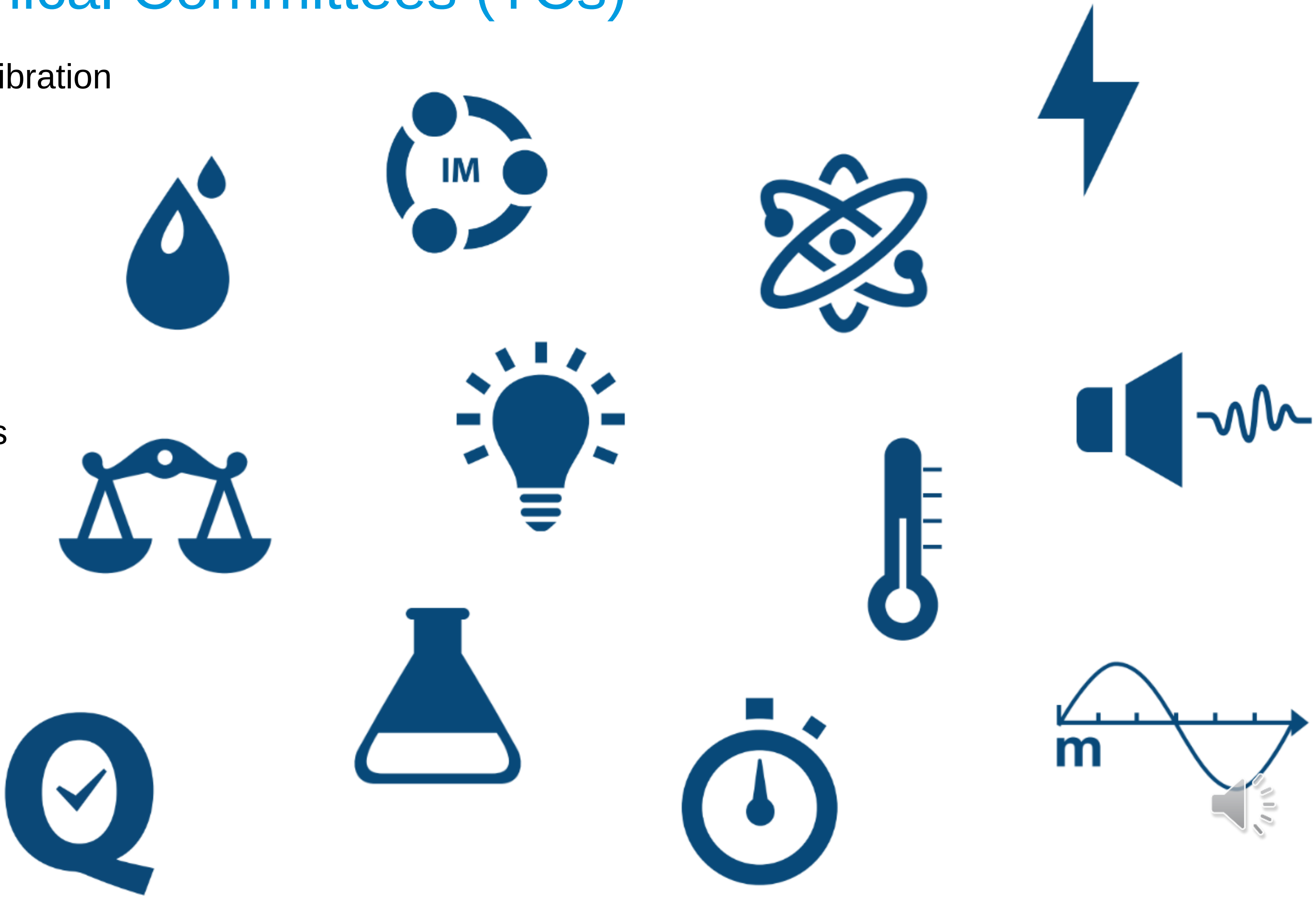
EURAMET is the Regional Metrology Organisation (RMO) of Europe. We coordinate the cooperation of National Metrology Institutes (NMI) and Designated Institutes (DIs) in Europe in fields such as research in metrology, traceability of measurements to the SI units, international recognition of national measurement 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.

https://www.euramet.org/about-euramet

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



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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 Qualidade

VSL National Metrology Institute

https://www.vsl.nl and https://www.ipq.pt

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 then 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 +/-0.5% of the volume indicated on the fuel dispenser. In the past, it was +/-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.

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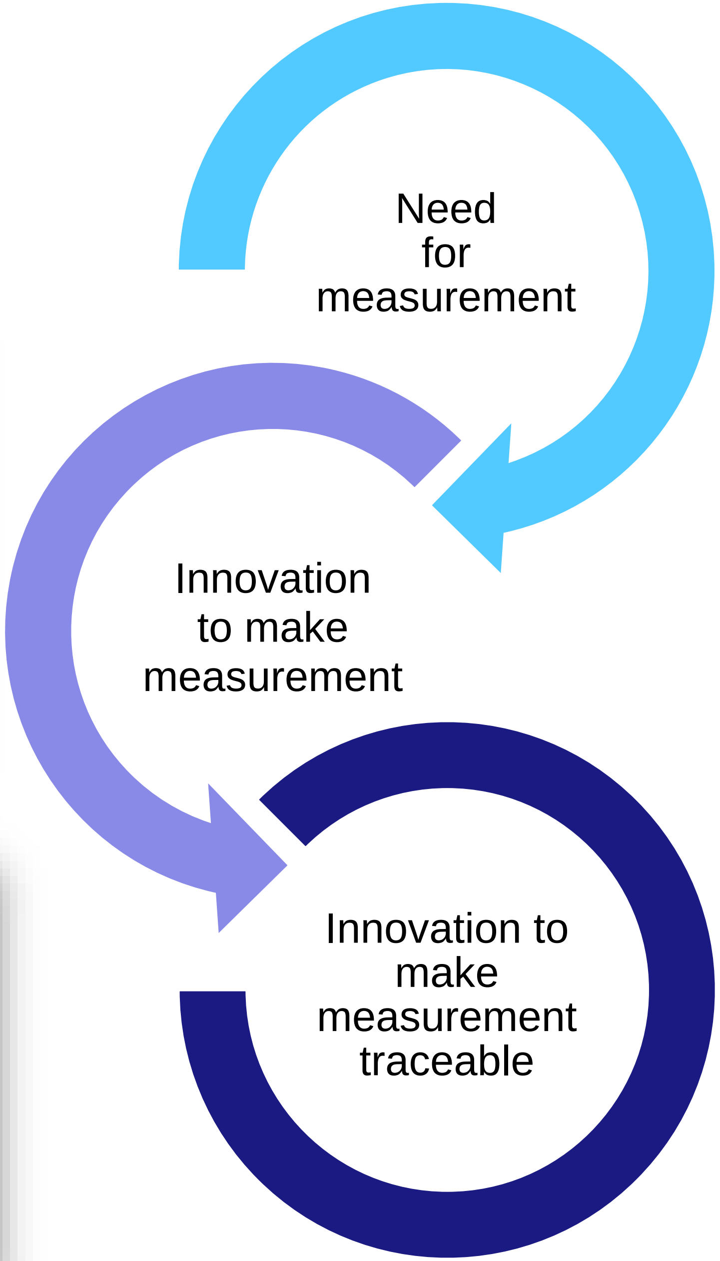
Make Measurable



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!

VSL
PO Box 654
2600 AR Delft
The Netherlands

T +31 15 269 15 00
F +31 15 261 29 71
E info@vsl.nl
I www.vsl.nl

Erik Smits
E fsmits@vsl.nl
T +31 15 269 15 96

Metrology