



# Role of metrology

Andy Henson

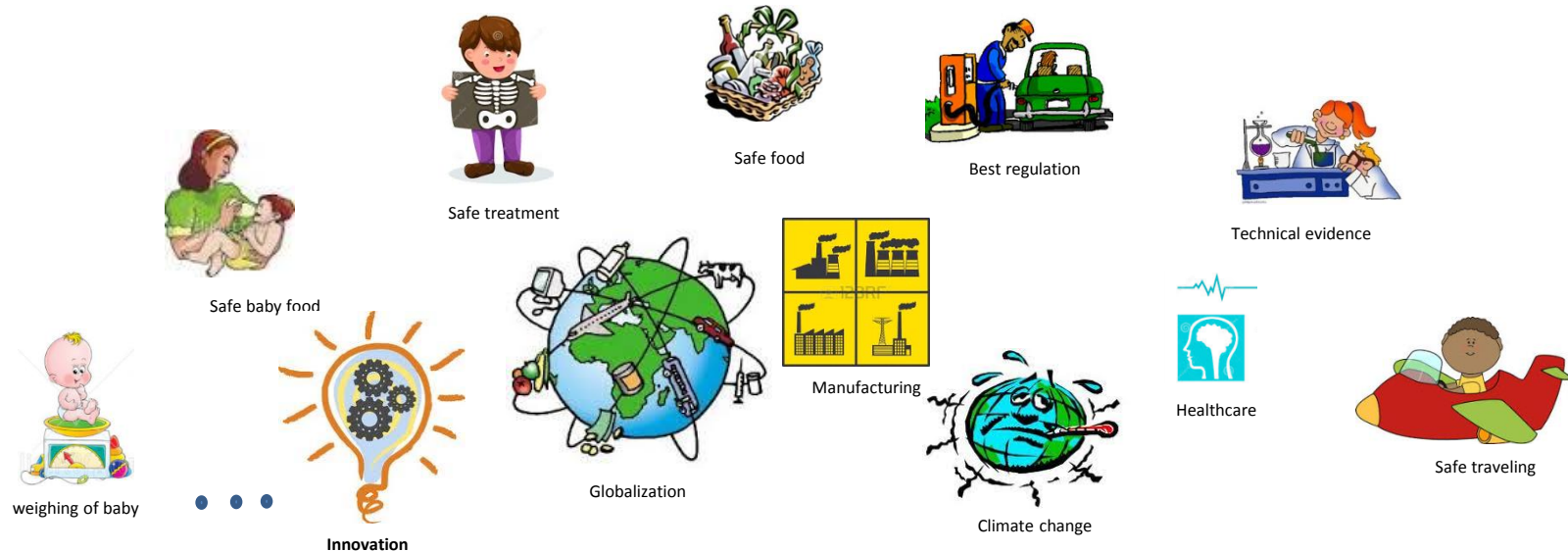
Director of the International Liaison and  
Communication Department

**BIPM**

**B**ureau  
♦ **I**nternational des  
♦ **P**oids et  
♦ **M**esures



# Metrology is a part of our lives from birth



- ◆ *Without metrology, you can't discover, design, manufacture, process, test, maintain, prove, buy or operate almost anything safely and reliably.*
- ◆ *From precision machined parts on engines down to tiny structures on micro and nano components, all require an accurate measurement that is recognized around the world.*
- ◆ *From filling your car with petrol to having an X-ray at a hospital, your life is surrounded by measurements.*

***Good measurement helps countries remain competitive, trade throughout the world and improve quality of life of their citizens.***

# The role of Metrology



- A new brochure highlights the contribution of metrology to the implementation of the 2030 Agenda for Sustainable Development
- Jointly developed by the UNIDO, the BIPM and the OIML.
- The partnership enables these three international organizations to coordinate their activities in complementary and mutually supportive areas of operation, in order to enhance the impact of industrial development on economic growth.

## UNIDO-BIPM-OIML joint publication



# Metrology is the “science and application of measurements”

An effective metrology system is characterized by the ability to properly calibrate measuring instrument with measurement uncertainties that are **fit for purpose**, against an appropriate reference via national standards (or CRMs).

Essential factors for effective metrology systems are:

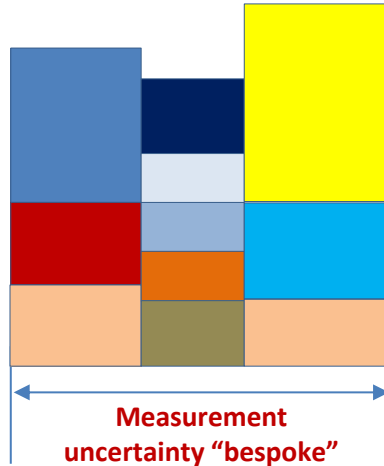
- traceability to SI, where possible or not yet possible, or internationally agreed reference materials or procedures
- regulated measurements and measuring instruments (in selected cases)
- confidence in testing and measurement results via certification, standardization, accreditation and calibration



# Fit for purpose

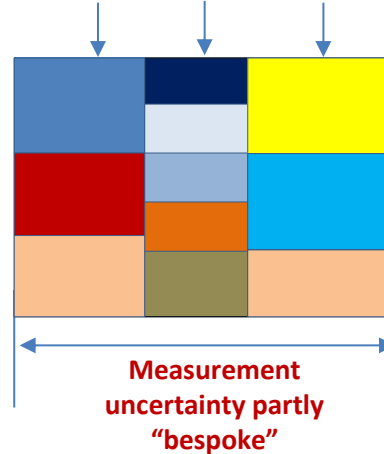
## Unregulated measurements

*(customer quality/price expectations/specifications)*



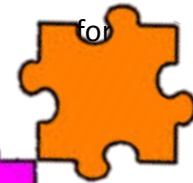
## Regulated measurements

**Ways to achieve**

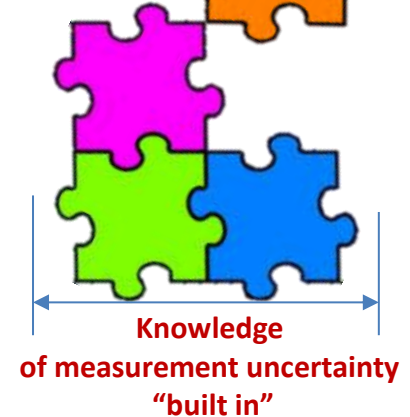


## Legally controlled measurement instruments

Dedicated measurement instruments



Dedicated measurement application



Increasingly easy to innovate

# Metrology is essential for...

Metrology influences, drives and underpins much of what we do and experience in our everyday lives.

## INDUSTRY & TRADE



## QUALITY of LIFE



## SCIENCE & INNOVATION



# Measurements must be...

## **Stable**

- ♦ Long-term trends can be used for decision making

## **Comparable**

- ♦ Results from different laboratories can be brought together

## **Coherent**

- ♦ Results from different methods can be brought together

**To meet the needs of the economy, society and citizens**

# Metrology

## Applied or industrial metrology

- **Applied or industrial metrology** concerns the application of measurement science to manufacturing and other processes and their use in society, ensuring the suitability of measurement instruments, their calibration and quality control of measurements.



Science  
Innovation  
Advanced manufacturing & process industries  
Complex service industries

Quality and Competition

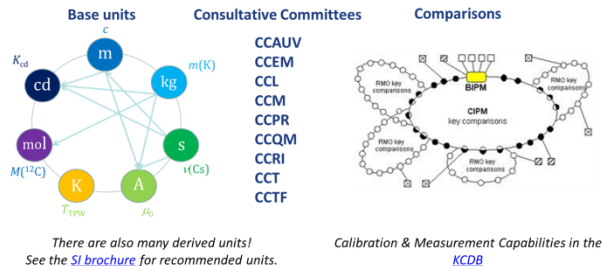
Trade

Economic well being

National well being

## Scientific or fundamental metrology

- **Scientific or fundamental metrology** concerns the establishment of measurement units, unit systems, the development of new measurement methods, realization of measurement units and the transfer of traceability from these standards to users in society.



## Legal metrology

- **Legal metrology** concerns regulatory requirements of measurements and measuring instruments for the protection of health, public safety, the environment, enabling taxation, protection of consumers and fair trade.



Science  
Health  
Safety  
Environment

Legislation and Regulation

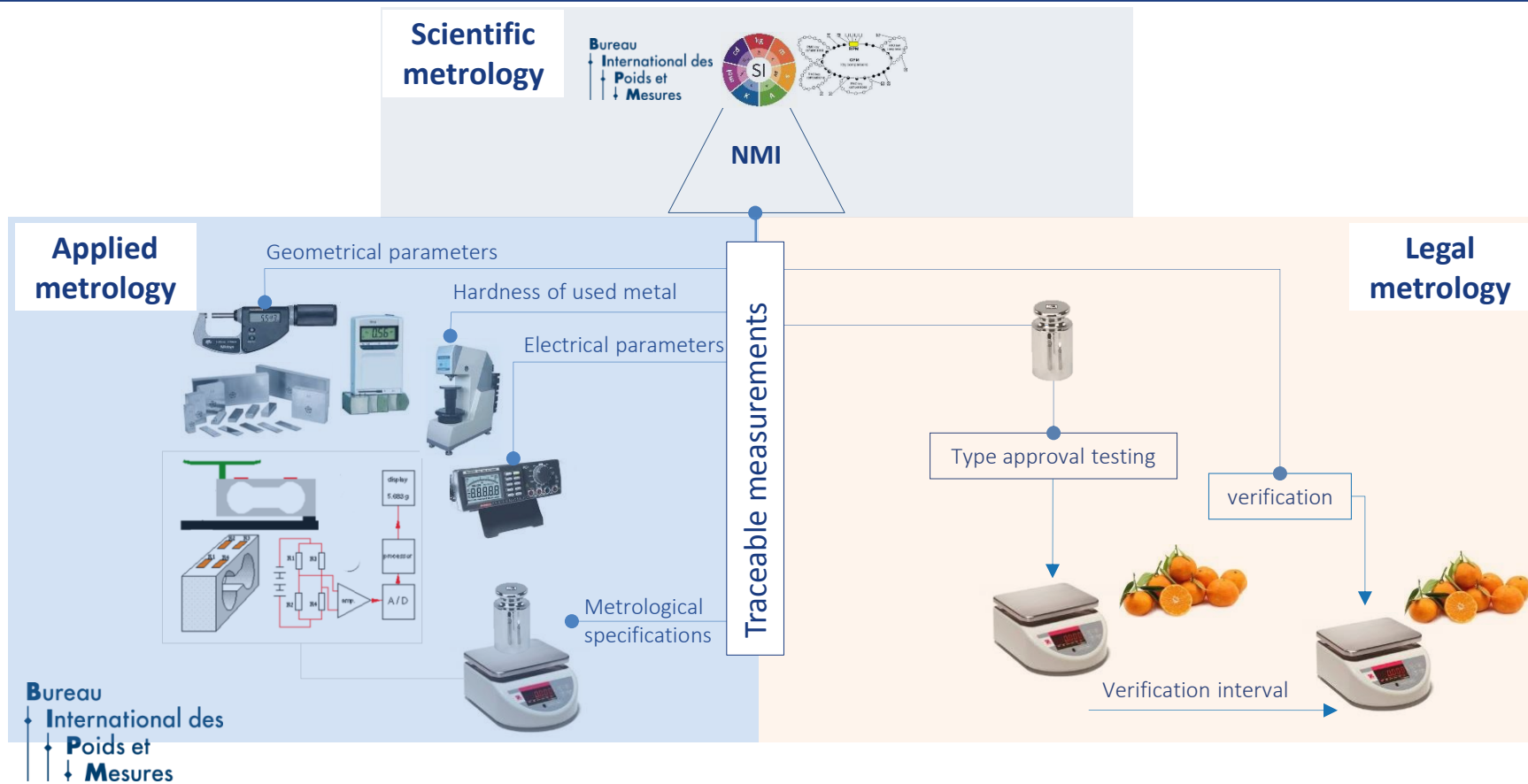
Security

Social well being

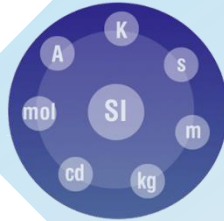
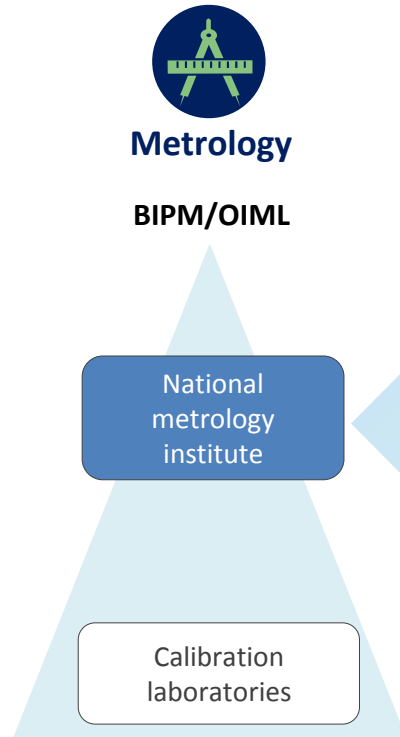
National well being



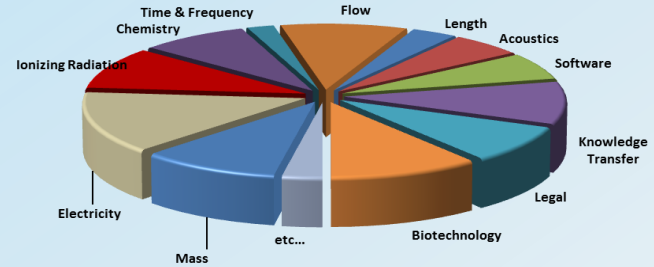
# In practice...



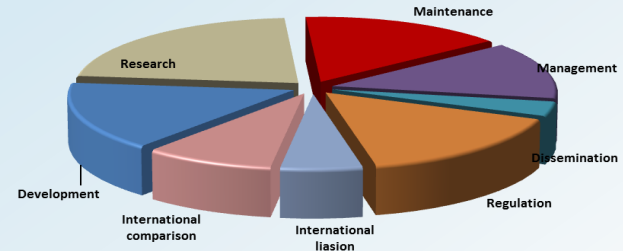
# Define the National needs in metrology



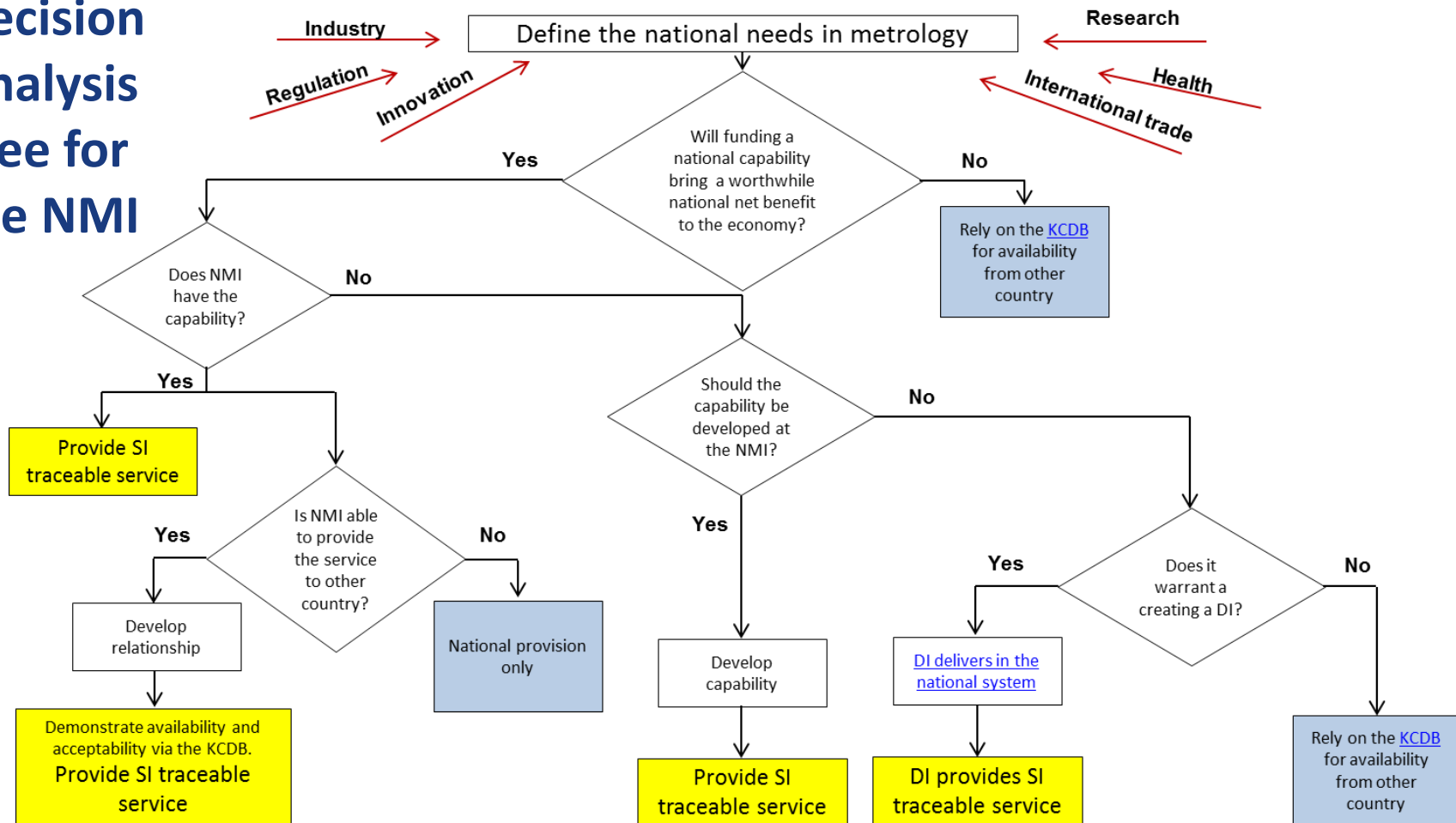
## ...where to focus recourses

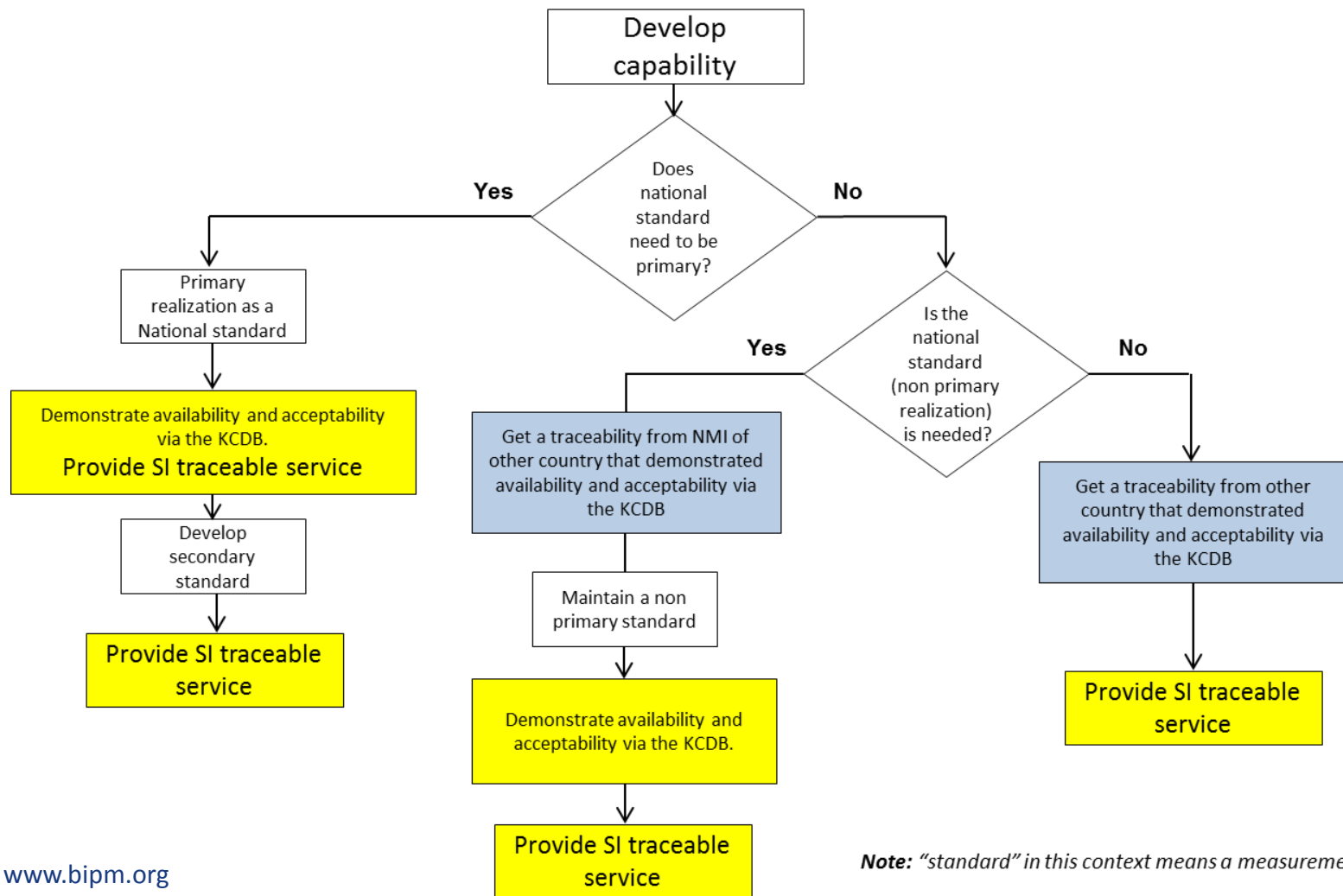


## ...and activities



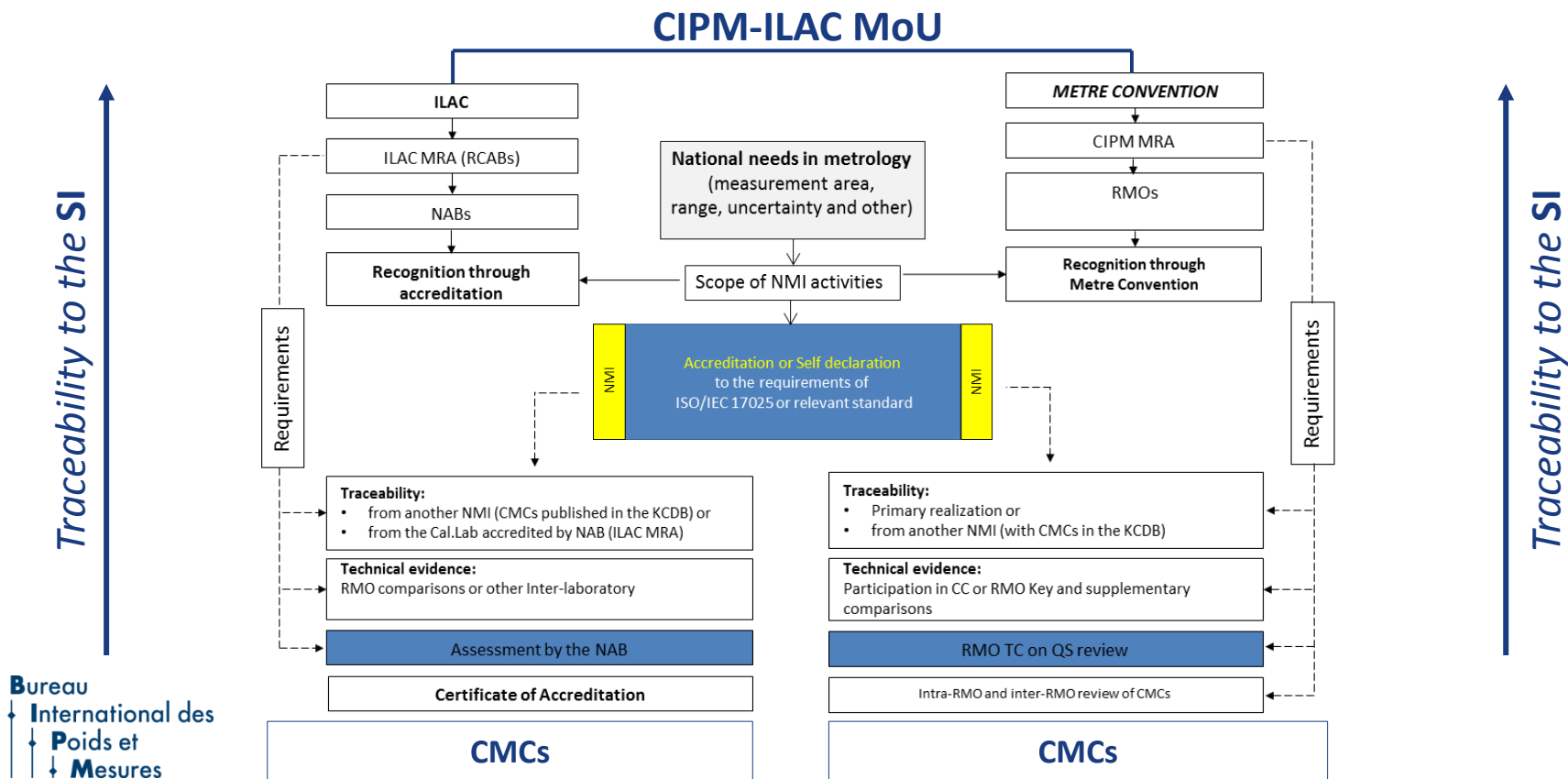
# Decision Analysis Tree for the NMI





**Note:** “standard” in this context means a measurement standard

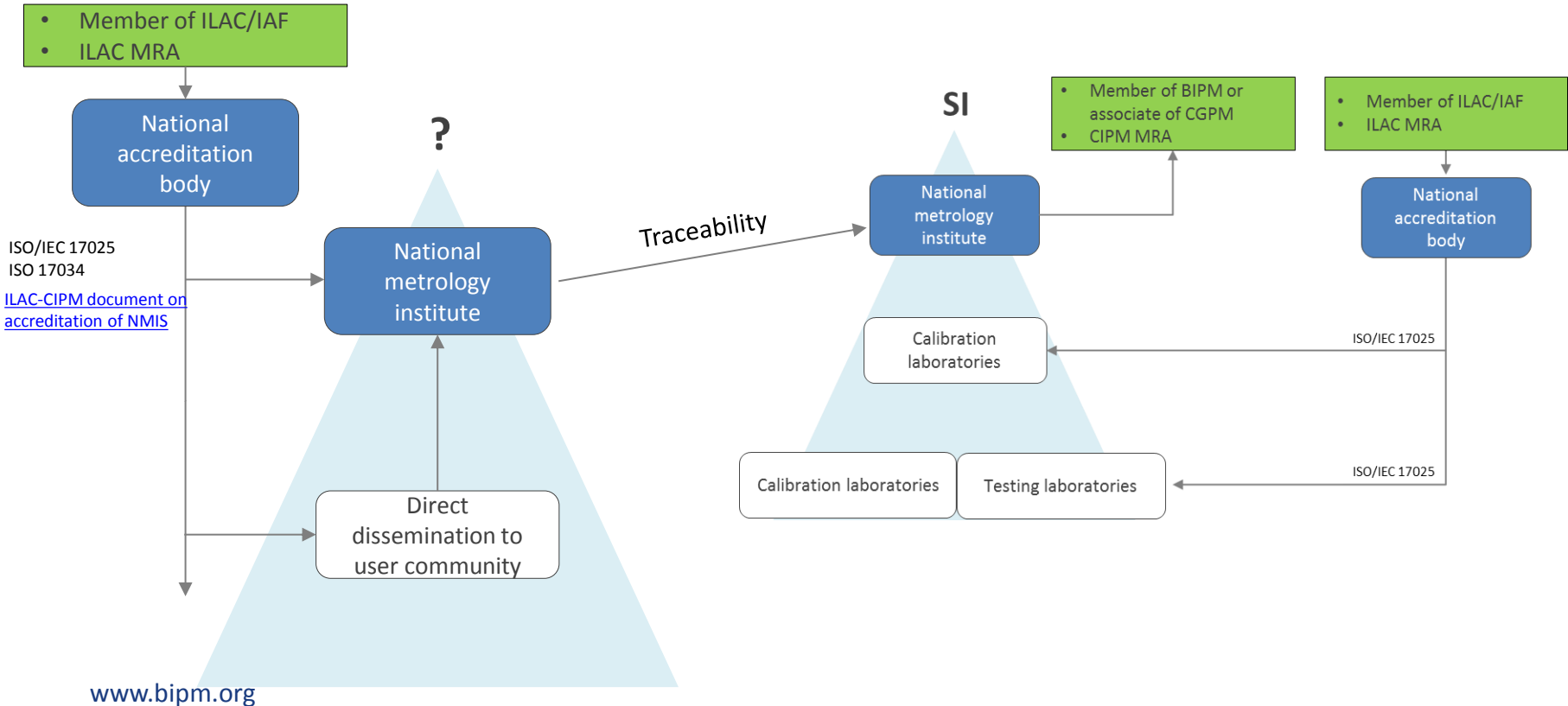
# Options for NMIs providing traceable services



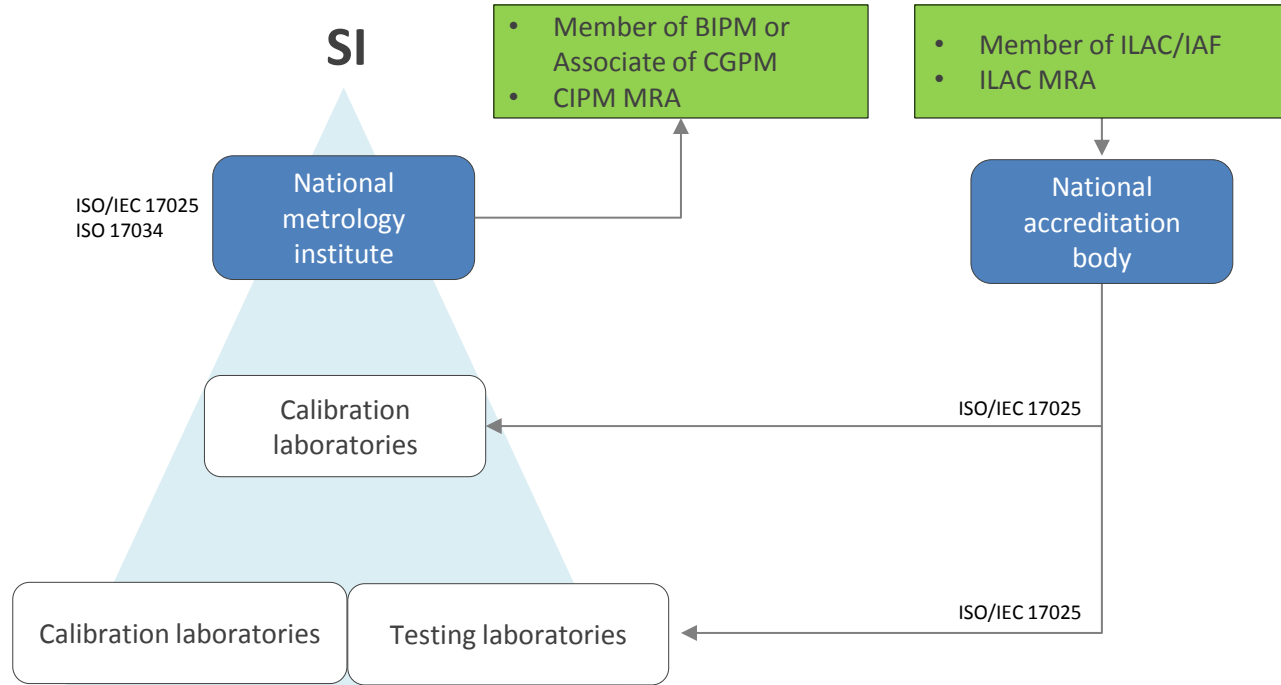
# Recognition through accreditation

Country A

Country B



# Recognition through *Metre Convention*



# Conclusion: Key challenges for the NMIs in the region

## Establishing and maintaining an NMI that:

- ◆ Operates a quality management system ISO/IEC 17025
  - and if relevant for reference materials ISO 17034
- ◆ Has national standards (primary realization or not as appropriate) for the highest priority national needs with the right balance of benefit verses cost.
  - Very low uncertainties are very expensive
  - Not realistic to provide every possible capability
  - Must be aligned the staff ability (evolve as needs change)
- ◆ Participates in accreditation and/or Metre Convention (CIPM MRA) to demonstrate capability and ensure international acceptability
- ◆ Disseminates SI traceability via the national standards to customers via calibration services and/or reference materials
- ◆ Provides advice to stakeholders/ customers related to the calibration services and other measurement challenges
- ◆ Provides advice to stakeholders/ customers on where to obtain internationally accepted traceable services when not provided by the NMI

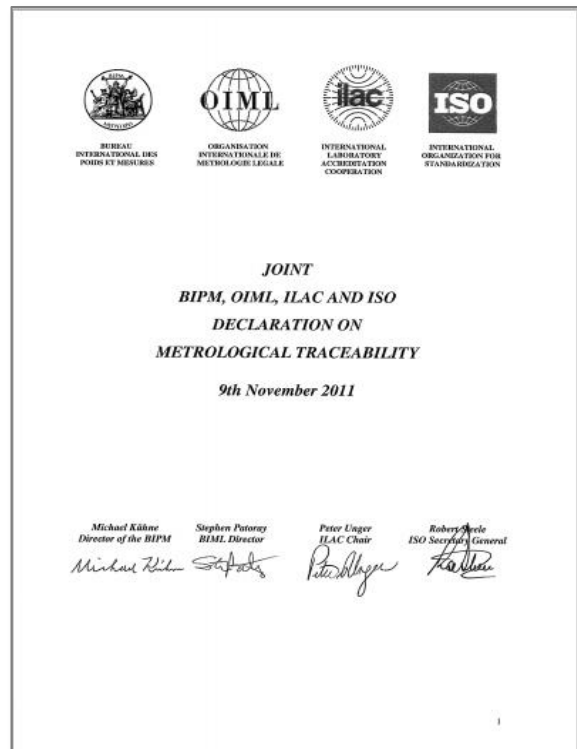




At the international level...

**Bureau**  
♦ **International des**  
♦ **Poids et**  
♦ **Mesures**

# Joint BIPM, OIML, ILAC and ISO declaration on measurement traceability



The 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 who should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB or
- in laboratories accredited by accreditation bodies which 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;

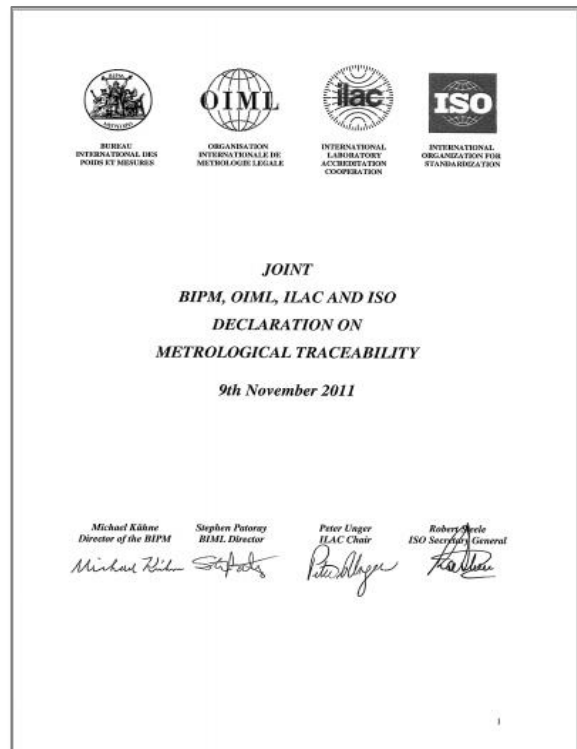
NMIs providing traceability for accredited laboratories should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB;

within the OIML's MAA, accreditation should be provided by bodies which are signatories to the ILAC Arrangement and the above policies on 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.

([http://www.bipm.org/utls/common/pdf/BIPM-OIML-ILAC-ISO\\_joint\\_declaration\\_2011.pdf](http://www.bipm.org/utls/common/pdf/BIPM-OIML-ILAC-ISO_joint_declaration_2011.pdf))

# Joint BIPM, OIML, ILAC and ISO declaration on measurement traceability



## Use of this Declaration

These principles underpin a world measurement system which provides a robust, internationally accepted framework within which users can have confidence in the validity and acceptability of measurements results. BIPM, OIML, ILAC and ISO strongly urge legislators and regulators to refer to the Arrangements described earlier in this Declaration and also to accept measurement results made within this system, thereby helping avoid technical barriers to trade. We also invite interested parties to endorse these principles and to make use of them in their own work.

*BIPM, OIML, ILAC and ISO meet annually at senior level in a 'Quadripartite' informal discussion on issues of common interest*

([http://www.bipm.org/utis/common/pdf/BIPM-OIML-ILAC-ISO\\_joint\\_declaration\\_2011.pdf](http://www.bipm.org/utis/common/pdf/BIPM-OIML-ILAC-ISO_joint_declaration_2011.pdf))

# OIML – Legal Metrology OIML D 1

## Art. 12: Traceability of measurement results

In the interests of free trade and the **avoidance of issues that might be perceived by other countries or the WTO as technical barriers to trade**, national requirements for traceability should be written carefully. **Ideally, traceability should always be specified as conforming to the SI system**, through realizations of the appropriate units and quantities at the NMI or at other countries' NMIs, rather than specifically to the NMI.

To establish whether foreign national standards meet the necessary requirements for traceability, **reference may be made of the CIPM MRA**. Under the CIPM MRA information is available in the KCDB, which is the publicly available database operated by the BIPM for that purpose. Inclusion in the KCDB provides a presumption of compliance with regard to traceability requirements. Where traceability cannot be established via the KCDB the CMA should establish the appropriate mechanism so that regulators have access to appropriate advice on whether alternative solutions are acceptable. Normally such advice would be provided by the NMI.

# OIML – Legal Metrology OIML D 1

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- Considerations for a Law on Metrology

## Element no. 3

*The Government shall designate the institute or institutes in charge of*

- keeping and maintaining the national measurement standards and providing traceability to the International System of Units(SI),*
- carrying out and/or coordinating the research work in metrology, and*
- carrying out and/or coordinating certain tasks in legal metrology.*

# Metrology and documentary standards

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NMIs (and designated institutes) **use and require within the CIPM MRA:**

- **ISO/IEC 17025: ‘General requirements for the competence of testing and calibration laboratories’** as their underpinning quality standard
- and, if involved in reference materials, **ISO 17034: ‘General requirements for the competence of reference material producers’**
  - As do tens of thousands of calibration and testing laboratories worldwide

NMIs (and designated institutes) **Provide**

- Experts to national standards body
- Experts to regional and international standards body technical committees and WGs

# Documentary standards - measurement

## ISO/IEC Documentary standards

- Use the International System of Units (SI)
- Require testing and calibration laboratories to be competent
- Embody measurement traceability
- ...and thus measurement uncertainty
  - Use of the VIM
  - Use of the GUM

## ISO/IEC 17025:2005 - General requirements for the competence of testing and calibration laboratories

### 5.6 Measurement

#### 5.6.1 General

All equipment used for environmental conditions, calibration or sampling shall be maintained in accordance with an established program.

NOTE Such a program shall include maintaining measurement equipment used to perform measurements.

#### 5.6.2 Specific requirements

##### 5.6.2.1 Calibration

5.6.2.1.1 For calibration, the laboratory shall be operated so as to ensure traceability to the International System of Units (SI).

A calibration laboratory shall ensure traceability to the SI by means of the standards of the SI. When using external calibration services, the laboratory shall ensure traceability. The calibration shall include the measurement specification (see annex A).

NOTE 1 Calibration shall be performed by a competent laboratory. A calibration shall be performed in accordance with the International Standard.

NOTE 2 Traceability (see VIM:1993, 6.4) of the measurement shall be recommended by the International System of Units (CIPM).

## ISO/IEC FDIS 17025:2017

g) the maintenance plan and maintenance program for the performance of the equipment;

h) details of any data.

### 6.5 Metrological traceability

6.5.1 The laboratory shall establish and maintain metrological traceability of measurement results by means of a documented unbroken chain of calibrations, each contributing to the measurement uncertainty, linking them to an appropriate reference.

NOTE 1 In ISO/IEC Guide 99, metrological traceability is defined as the 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 See Annex A.

6.5.2 The laboratory shall ensure metrological traceability of Units (SI) through one of the following:

a) calibration provided by a competent laboratory;

NOTE 1 Laboratories fulfilling the requirements of ISO/IEC 17025 shall be competent.

b) certified values of certified reference materials demonstrating metrological traceability to the SI;

NOTE 2 Reference material competent.

c) direct realization of the SI units ensuring metrological traceability to the International or national standards.

NOTE 3 Details of practical realization of the definitions of some international units are given in the SI brochure.

6.5.3 When metrological traceability is demonstrated, the laboratory shall demonstrate metrological traceability:

a) certified values of certified reference materials;

b) results of reference measurement procedures clearly described and accepted as providing metrological traceability and ensured by suitable comparison.

‘shall ensure that measurement results are traceable to the SI’

‘unbroken chain of calibrations’

‘direct realization of the SI’

‘shall demonstrate metrological traceability’

# Metrology and documentary standards

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NMIs (and designated institutes) **Use and require within the CIPM MRA:**

- **ISO/IEC 17025: ‘General requirements for the competence of testing and calibration laboratories’** as their underpinning quality standard
- and, if involved in reference materials, **ISO Guide 34: ‘General requirements for the competence of reference material producers’**
  - As do tens of thousands of calibration and testing laboratories worldwide

NMIs (and designated institutes) **Provide**

- Experts to national standards body
- Experts to regional and international standards body technical committees and WGs



# Documentary standards - measurement

The image displays three overlapping screenshots of the ISO Online Browsing Platform (OBP) search interface. Each screenshot shows the ISO logo, a search bar, and search results. Red circles highlight the search results counts for specific queries.

**Top Screenshot:** Search for "measurement" yields 12,479 results. The interface includes a search bar with a magnifying glass icon, a "Search results" button, and a "Sort by: Relevance" dropdown. The results per page are set to 10.

**Middle Screenshot:** Search for "testing" yields 19,816 results. The interface is identical to the top screenshot, showing the search bar, results count, and sorting options.

**Bottom Screenshot:** Search for "calibration" yields 5,520 results. This screenshot shows a detailed view of the search results, including a list of standards and their details. The results are sorted by relevance, and the results per page are set to 10. The list of standards includes:

- Standards:** 16426
- Collections:** 2
- Publications:** 24
- Graphical symbols:** 3364
- Terms & Definitions:** 3364
- Country codes:** 3364

The detailed view of the standards includes the following information:

- Paints and Varnishes:** A collection of more than 2 their manufacture. Standard no.: IEC 60417
- Lamp test:** Reference number: 5857, Standard no.: IEC 60417
- Pressure testing facility:** Reference number: X10, Standard no.: ISO 14617
- Phase calibration:** Reference number: 5201, Type: For use on equipment, Available formats: PDF, Standard no.: IEC 60417, Committee: IEC/SC 3C
- Calibration:** Reference number: 0160, Type: For use on equipment, Available formats: AI, DWG, EPS, Standard no.: ISO 7000, Committee: ISO/TC 145/SC 3
- Angle calibration:** Reference number: 5202, Type: For use on equipment, Available formats: PDF, Standard no.: IEC 60417, Committee: IEC/SC 3C
- ISO 16063-45:2017(en):** Methods for the calibration of vibration and shock transducers — Part 45: In-situ calibration of transducers with built in calibration coil
- ISO 8466-2:2001(en):** Water quality — Calibration and evaluation of analytical methods and estimation of performance characteristics — Part 2: Calibration strategy for non-linear second-order calibration functions

The bottom screenshot also shows a list of standards with their reference numbers, types, available formats, standard numbers, and committees. The results are sorted by relevance, and the results per page are set to 10.

# Metrology and Accreditation

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All laboratories, including NMIs must demonstrate their competence for international and national acceptability, at NMI level that is review via the CIPM MRA

*About half of the NMI community also choose to be accredited*

Beyond the NMIs, the main generic assurance is via accreditation by a accreditation body that participates in ILAC (usually via a regional arrangement)

- **Some 55 000 calibration and testing laboratories worldwide choose accreditation**

NMIs **provide** technical experts to the accreditation bodies to help review top level calibration labs and other NMIs.

- And of course other metrology organisations provide experts, especially for more routine accreditations

## Accreditation – ILAC policy on metrological traceability of measurement results (ILAC P10)

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- [ILAC P10:01/2013 ILAC Policy on Traceability of Measurement Results](#)  
This document describes the ILAC policy on metrological traceability of measurement results.

### **ILAC POLICY FOR TRACEABILITY COVERED BY THE ILAC ARRANGEMENT IN CALIBRATION**

The general requirement for traceability in ISO/IEC 17025:2005 is:

*5.6.1 All equipment used for tests and/or calibrations, including equipment for subsidiary measurements (e.g. for environmental conditions) having a significant effect on the accuracy or validity of the result of the test, calibration or sampling shall be calibrated before being put into service.*

*5.6.2.1.1 For calibration laboratories, the programme for calibration of equipment shall be designed and operated so as to ensure that calibrations and measurements made by the laboratory are traceable to the International System of Units (SI) (Système international d'unités).*

Clause 5.6.2.1.1 in ISO/IEC 17025:2005 further states that “*When using external calibration services, traceability of measurement shall be assured by the use of calibration services from laboratories that can demonstrate competence, measurement capability and traceability*”.

Clause 5.6.2.1.1 in ISO/IEC 17025:2005 further states that “*When using external calibration services, traceability of measurement shall be assured by the use of calibration services from laboratories that can demonstrate competence, measurement capability and traceability*”. For equipment and reference standards that must be calibrated, the ILAC policy is that they shall be calibrated by:

1. An NMI participating in the CIPM MRA
2. Accredited lab covered by the ILAC Arrangement or by Regional Arrangements recognised by ILAC
3. Other possibilities:
  - a) NMI outside the CIPM MRA
  - b) Other lab

# Metrology, Accreditation and Standards

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Takeaway message.....

At national level the relationship between the NMI, the national standards body and the national accreditation body\* is important....

If it isn't good....

**FIX IT!**

*\*Recalling that in some countries its not a single accreditation body, and there may be many standards developers too*

# Impact routes (II) Trade and development

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There are two crucial elements for developing countries to increase trade and trade (national and international) move up the 'value chain':

**To be able to jump over regulatory hurdles to gain market access**

**To produce goods (and sometimes services) at a quality/price point attractive to the market**

*Effective manufacturing and conformity assessment depends on the quality infrastructure (metrology, international standards, accreditation)*

# The SI

**Bureau International des Poids et Mesures**

– the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards

ABOUT US WORLDWIDE METROLOGY INTERNATIONAL EQUIVALENCE MEASUREMENT

## SI Brochure: The International System of Units (SI) [8th edition]

List of contents Download PDF files Mises en pratique DRAFT 9th edition

→ We are pleased to present the updated (2014) 8th edition of the SI Brochure presents the *Système International d'Unités*, the SI (known in English as the International System of Units)

### • Preface to the 8th edition

#### ▼ Chapter 1: Introduction

- Quantities and units
- The International System of Units (SI) and the corresponding system of quantities
- Dimensions of quantities
- Coherent units, derived units with special names, and the SI prefixes
- SI units in the framework of general relativity
- Units for quantities that describe biological effects
- Legislation on units
- Historical note

#### ► Chapter 2: SI units

#### ► Chapter 3: Decimal multiples and submultiples of SI units

#### ► Chapter 4: Units outside the SI

#### ► Chapter 5: Writing unit symbols and names, and expressing the values of quantities

Search facility:

ISO 80000-1:2009  
Quantities and units -- Part 1

**Abstract**

ISO 80000-1:2009 gives general information and definitions of quantities, units, quantity and unit symbols, and the International System of Quantities, ISQ, and the International System of Units, SI.

The principles laid down in ISO 80000-1:2009 are the basis for the development of standards and as an introductory units series.

Ordinal quantities and nominal properties are outside the scope of this part of ISO 80000.

General information Revisions Comments

Document published on: 2009-11-15

Edition: 1 (Monolingual) ICS: 01.040.01

Status: Published Staged: No

TC/SC: ISO/TC 12 Number: 1

## Consultative Committee for Units (CCU)

Members Criteria for membership CCU

### President:

Prof. J. Ullrich  
President of the PTB, Vice-President of the CIPM  
Physikalisch-Technische Bundesanstalt  
Germany

### Executive Secretary:

Dr E. de Mirandés  
CCU Executive Secretary  
Bureau International des Poids et Mesures  
France

### Member(s):

- Centro Español de Metrología [CEM], Madrid
- Commission internationale de l'éclairage [CIE]
- Committee on Data for Science and Technology [CODATA Task Group on Fundamental Constants]
- Federal Agency on Technical Regulating and Metrology [Rosstandart], Moscow
- International Astronomical Union [IAU]
- International Commission on Radiation Units and Measurements [ICRU]
- International Electrotechnical Commission [IEC]
- International Federation of Clinical Chemistry and Laboratory Medicine [IFCC], Milan
- International Organization for Standardization [ISO]
- International Organization of Legal Metrology [OIML]
- International Union of Pure and Applied Chemistry [IUPAC]
- International Union of Pure and Applied Physics [IUPAP]
- National Institute of Metrology [NIM], Beijing
- National Institute of Standards and Technology [NIST], Gaithersburg
- National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba
- National Physical Laboratory [NPL], Teddington
- Physikalisch-Technische Bundesanstalt [PTB], Braunschweig

### Personal member(s):

- Prof. M. Himmert
- Dr T.J. Quinn, CBE FRS

### Honorary member(s):

- Prof. I.M. Mills, OBE FRS

### Note:

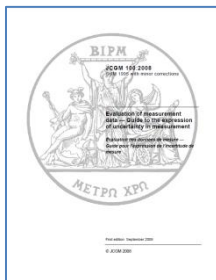
The Director of the BIPM is a member, *ex officio*, of all Consultative Committees.



# VIM & GUM

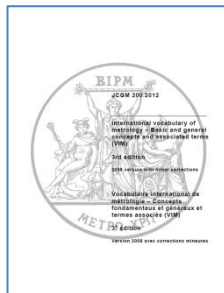
## GUM

[Guide to the Expression of Uncertainty in Measurement](#)  
ISO/IEC Guide 98



## VIM

[International Vocabulary of Metrology](#)  
ISO/IEC Guide 99



**Bureau International des Poids et Mesures** – the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

Search facility:

### Joint Committee for Guides in Metrology (JCGM)

ABOUT U > You are here

**Joint Committee for Guides in Metrology (JCGM)**

JCGM Mission Members JCGM Charter WG1 WG2 JCGM publications Members' working area



- Chairman: Dr Martin Milton
- BIPM contact: Mr Robert Sitton
- Contact form: [✉](#)

→ **Member organizations:**

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The Joint Committee on Traceability in Laboratory Medicine (JCTLM) was created to meet the need for a worldwide platform to promote and give guidance on internationally recognized and accepted equivalence of measurements in laboratory medicine and traceability to appropriate measurement standards. These are embodied in ISO 17511, 17025 and 18153. The JCTLM created two working groups:

- WG1 Reference Materials and Reference Measurement Procedures
- WG2 Reference Measurement Services

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Database of higher-order reference materials,  
measurement methods/procedures and services

JCTLM Database  
Laboratory medicine and *in vitro* diagnostics

> You are here : JCTLM-DB

**JCTLM database: Laboratory medicine and *in vitro* diagnostics**

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**Analyte keyword search for reference materials, measurement methods/procedures and services**

Type an analyte name in part or full, e.g. cholesterol

Refine search by analyte category: All
 Refine search by matrix category: All

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Select an analyte category:



## World Metrology Day joint BIPM and OIML initiative

*The international metrology community which works to ensure that accurate measurements can be made across the world **endeavors to raise awareness each World Metrology Day through a poster campaign and web site.***

# World Metrology Day 2017 - “Measurements for transport”



The needs for new and improved means of transport are clear, it is also important that they meet increasing requirements for economy and environmental performance. Some of the most demanding that are underpinned by the work of national metrology institutes include:



accurate and rapid weighing of shipping containers to ensure the safe loading of container ships



characterisation of low friction surfaces and aerodynamic shapes of aircraft to minimize fuel consumption



valid measurements of the chemical composition of vehicle emissions to support regulators and city authorities in controlling pollution levels

# World Metrology Day 2017 - “Measurements for transport”



Safety of Life at Sea (SOLAS) convention requires verification of container weights before loaded containers may be placed aboard ships.

## ***Accurate weighing of shipping containers required for:***

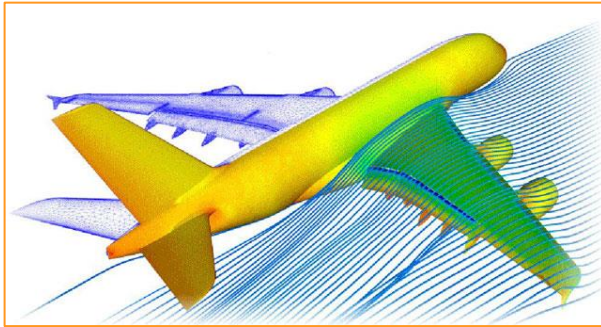
- *Reducing the number of accidents of container ships*
- *Securing the cargo*
- *Application of tax legislation of different countries*
- *Reducing transportation costs*
- *Meeting regulatory requirements*



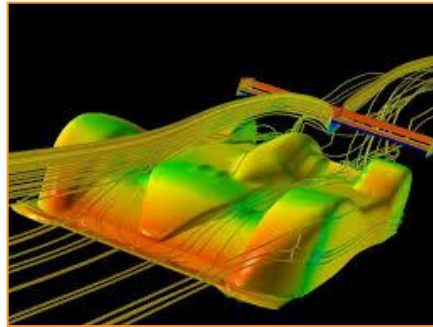
# World Metrology Day 2017 - “Measurements for transport”



Characterisation of low friction surfaces and aerodynamic shapes of aircraft to minimize fuel consumption



*Less fuel = lower emissions and cost*



*Aerodynamics is the utmost important factor in Formula One car performance*



*Minimizing the aerodynamic drag of the train remains a key issue for high-speed trains*

# World Metrology Day 2017 - “Measurements for transport”



Valid measurements of the chemical composition of vehicle emissions to support regulators and city authorities in controlling pollution levels

*The air pollutant emissions from transport are a significant contribution to the overall state of air quality in the world*

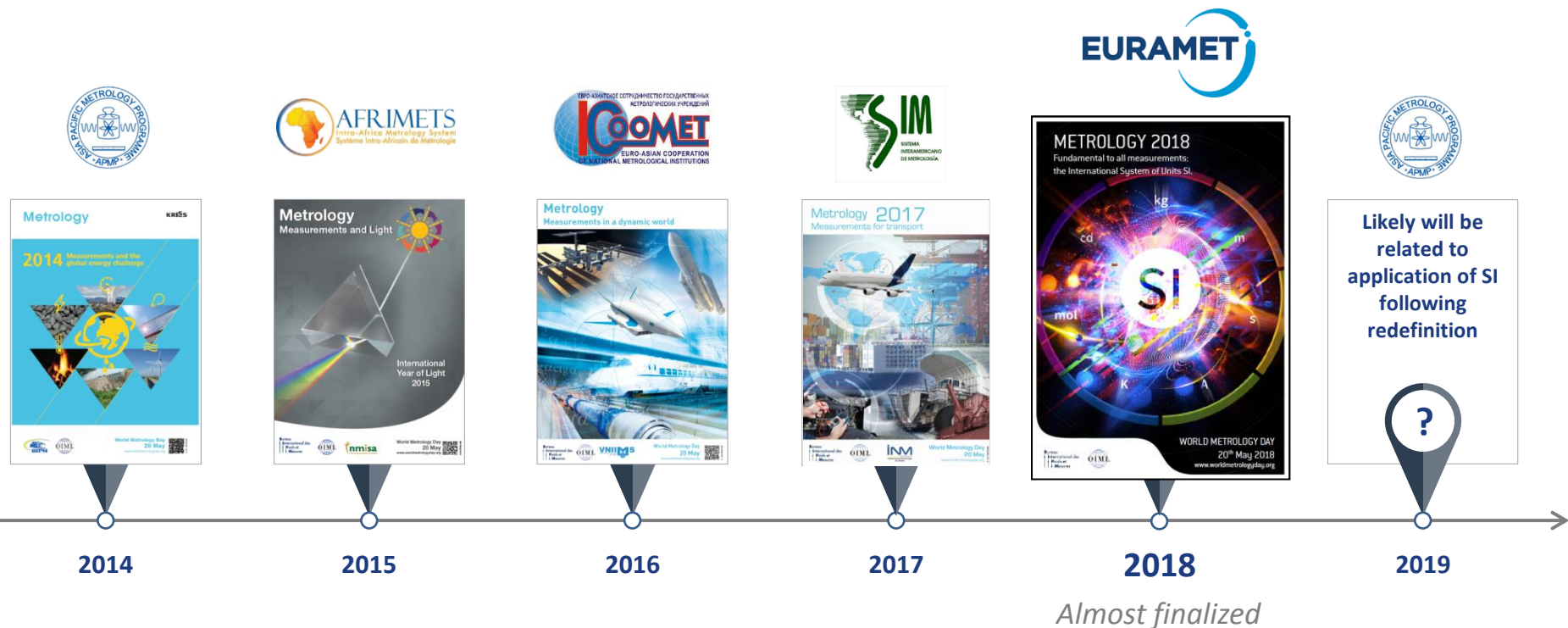


*Tough requirements change the technology of vehicles*





# World Metrology Day posters





# Conclusions

- ◆ Metrology is a integrated task with scientific, legal, industrial ... aspects.
- ◆ The world economy, society and citizens depend on the international “quality infrastructure” which depends on metrology.
- ◆ Metrology provides:
  - Measurements that are stable ... comparable ... and coherent.
- ◆ The true challenge is to provide measurement standards “for all people for all times”.
- ◆ The use of defining constants provides one aspect of this – there are many others.
  - ◆ Redefinition of SI ensures that role of metrology remained reliable at science and technology advanced.





Thank you

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