Metrology – an international endeavour

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Metrology – an international endeavour

There are many interesting things I could cover in a talk on this topic....

• The world system of metrology (the SI)
• CIPM MRA
• Research collaborations
• **Quality Infrastructure**
Quality Infrastructure (QI)

There are various definitions of quality infrastructure (sometimes referred to as the *technical infrastructure*)

All include (at least):

- **metrology**
- **documentary (written) standards**
- **(laboratory) accreditation**
National Quality Infrastructure

“The NQI are the national institutions that provide the framework and services to advance the quality and safety of products and services offered in local and foreign markets.”

IAAC at the WTO

And internationally the QI is the sum of the NQI + the transnational institutions and systems that effectively link them
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 measurement “traceability chain”

Slide courtesy
Dr S Davidson, NPL, UK
National ‘fan out’ of the metrological traceability chain
Impact routes

Measurements technologies

Measurement methods

Nationally and internationally aligned standards

Generate, optimise and assure confidence in the technical data innovators need to -

Widely understood

Validate new ideas

Reduce new product time to market

Accelerate processes

Improve process efficiency

Reduce waste/downtime

Increase reliability

Extend the operating envelope

Meet standards/regulation

Sometimes understood

Rarely understood

Validate new ideas

Reduce new product time to market

Accelerate processes

Improve process efficiency

Reduce waste/downtime

Increase reliability

Extend the operating envelope

Meet standards/regulation
### Impact routes

**Metrology is a key **enabling technology**...**

Yet its (potential) **contribution** .... **is often overlooked**

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<tr>
<th>Measurement technologies</th>
<th>Validate new ideas</th>
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<td>Measurement methods</td>
<td>Reduce new product time to market</td>
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The role of Quality in trade (domestic and international)

EU example

One way of looking at quality in trade - single market

Quality meeting expectations

Unregulated

voluntary codes of practice in some sectors

performance standards (in many cases)

Regulated

Directives (transposed into MS legislation)

Old Approach specifies what and how

Regulations (directly and immediately applicable)
The role of Quality in trade (domestic and international)

**EU example**

One way of looking at quality in trade - single market

- **Quality meeting expectations**
  - **Unregulated**
    - voluntary codes of practice in some sectors
      - performance standards (in many cases)
  - **Regulated**
    - Directives (transposed into MS legislation)
      - Old Approach specifies what and how
    - Regulations (directly and immediately applicable)
      - New Approach essential requirements only
        - Mandated standards (documentary standards)

Global approach (to conformity assessment)
The role of Quality in trade (domestic and international)

One way of looking at quality in trade - single market

Unregulated

- voluntary codes of practice in some sectors
- performance standards (in many cases)

Regulated

- Directives (transposed into MS legislation)
- Regulations (directly and immediately applicable)

Quality meeting expectations

Old Approach

specifies what and how

New Approach

essential requirements only

Mandated standards (documentary standards)

Yes = access to the market
No = exclusion from the market

Remember, compliance doesn't mean anyone will buy!

An assessment of conformity is required, this may be a manufacturer’s declaration, or more detailed testing/certification by, typically a notified body + Possible market surveillance

Help demonstrate added value and differentiate product

There may be additional performance standards for the product

Traceability/measurement uncertainty in legal metrology

Regulatory requirements

Unregulated measurements (customer quality/price expectations/specifications)

Measurement uncertainty “bespoke”

Regulated measurements

Ways to achieve

Measurement uncertainty partly “bespoke”

Legally controlled measurement instruments

Dedicated measurement instruments

Dedicated measurement application

Knowledge of measurement uncertainty “built in”

Increasingly easy to innovate
Trade - WTO Agreement on Technical Barriers to Trade (TBT)

**TBT Agreement**

*Pursuit of trade liberalization...*
- avoiding unnecessary/discriminatory barriers to int’l trade

*Right of Members’ to regulate...*
- allowing Members to pursue legitimate objectives at levels they consider appropriate

*use of international standards...* *as a basis for regulation...* *Harmonization*
Scope of the TBT Agreement

TBT Measures...

Technical Regulations

Standards

Conformity Assessment Procedures

...related to all products (industrial and agricultural) (Art. 1.3)
Conformity Assessment Procedures (CAP)

“Any procedure used, directly or indirectly, to determine that relevant requirements in technical regulations or standards are fulfilled.”
The value of documentary standards and accreditation is directly recognised.

The value of metrology is indirectly recognised.

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**Arrangements to facilitate CAP**

(encouraged in TBT Agreement)

- International or regional systems for conformity assessment
  - “Members shall, wherever practicable, formulate and adopt international systems for conformity assessment”
  - Systems such as ILAC/IAF, IECEE CB are increasingly prominent in TBT Committee discussions

- Recognition of foreign conformity assessment results
  - “verified compliance, for instance through accreditation, with relevant guides or recommendations issued by international standardizing bodies shall be taken into account as an indication of adequate technical competence”
Do we all use the same definition of Quality Infrastructure?

- There are various definitions of quality infrastructure (sometimes referred to as the technical infrastructure)
- All link metrology, documentary (written) standards, and accreditation
- They often also explicitly include conformity assessment in some way
  - At its simplest, "conformity assessment" means checking that products, materials, services, systems or people measure up to the specifications of a relevant standard.
  - So often that means testing, which means measurement

*So let's take a look at a selection of the descriptions.....*
Measurement standards are provided through an internationally recognized framework through which suppliers of products can demonstrate compliance with specification.
QI - various models (2)
QI - various models (2)

- Accredited calibration and testing laboratories
- Calibration and testing laboratories
- Measurement instruments

- ISO/IEC 17025
- ISO Guide 34
- ILAC-CIPM document on accreditation of NMIS

ISO/IEC 17011

- ISO 14000
- ISO 22000 etc...

- ISO/IEC 17025
- ISO 9001, etc...

ILAC-CIPM document on accreditation of NMIS

ISO/IEC 17025

- GUM
- VIM

JCGM:
- BIPM
- ILAC
- ISO
- IFCC
- IUPAC
- IUPAP
- OIML

www.bipm.org
QI - various models (3)
QI - various models (4)

African Quality Infrastructure has three key elements namely: metrology, standardization and accreditation of conformity assessment services such as certification, testing, calibration and inspection

These elements are independently managed however, they form a close network based on a technical hierarchy.

Accreditation
Recognition of technical competence

Standards
Definition of properties, dimensions, tolerances, etc.

Conformity assessment
Conformity with requirements defined by standards

Metrology
Guarantee of exact and reliable measurements
QI - various models (6)
UNIDO
Quality Infrastructure is generally understood to be the totality of the institutional framework (public and private) required to establish and implement standardization, metrology (scientific, industrial and legal), accreditation and conformity assessment services (inspection, testing and product- and system certification) necessary to provide acceptable evidence that products and services meet defined requirements, be it demanded by authorities or the market place.

https://www.unido.org/fileadmin/user_media_upgrade/What_we_do/Topics/Competitive_and_trade/5_QI_highres.pdf
The 'quality infrastructure' ...comprises the physical facilities and the interrelated systems of organisations, structures and people that help organisations to implement quality practices and improve performance.

The principle parts of the infrastructure relate to:
- regulation - government, regulators
- standards - documentary, physical/ reference, other codified intellectual property
- conformity assessment and accreditation
- economic operators and their collective representatives
- consumers


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QI: Point to note!

...so many definitions and diagrams!

...IT DOES NOT MATTER!

*It's fine to define QI in a way appropriate for the circumstance...*

But the lesson to take away..

**Metrology doesn’t and can’t work in a vacuum...!**
Key QI players at international level

There are many, many other players! ....often sector or regionally focuses
QI links at national level

- National links
- Regional links
- International institutional links
Metrology and documentary standards

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
Metrology and Accreditation

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
Metrology, Accreditation and Standards

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
QI links at regional level

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<tr>
<th>Region</th>
<th>Europe</th>
<th>Americas</th>
<th>Asia Pacific</th>
<th>Central Asia</th>
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Not comprehensive!
Linking the QI elements at regional level - the Americas

AMONG

The Inter-American Accreditation Cooperation (IAAC)
AND
The Inter-American Metrology System (SIM)
AND
The Pan-American Standards Commission (COPANT)

ARTICLE I
PURPOSE

The purpose of this MOU is to create the Quality Infrastructure Council of the Americas, a partnership of peer regional organizations that provides a single point of contact for action and collaboration to support the expansion of National Quality Infrastructure in the Hemisphere. Cooperative activities will be explored and determined by the Parties within the framework of this MOU.
Linking the QI elements at regional level - the Africa
BIPM and the international QI

• BIPM promotes the interests of its Member states within the scope of the Metre Convention
  • Scientific coordination
  • International liaison

And the BIPM and its NMI community have extensive QI links

.... Lets take a look
The SI
VIM & GUM

GUM

*Guide to the Expression of Uncertainty in Measurement*

VIM

*International Vocabulary of Metrology*

www.bipm.org
Joint Committee for Traceability in Laboratory Medicine (JCTLM)

BIPM
IFCC
ILAC

Agree to cooperate to establish a Joint Committee for Traceability in Laboratory Medicine, with the acronym JCTLM.

‘The goal of the JCTLM is to provide 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.’
DCMAS Network

What we do?

DCMAS Network: A network on metrology, accreditation and standardization for developing countries. This initiative seeks to bring together all specialized organizations that operate at an international level and that are active in promoting and implementing MAS activities (metrology, accreditation, standardization and conformity assessment) as a tool for sustainable economic development.

Member Organisations

- BIPM Bureau International de Poids et Mesures
- IAF International Accreditation Forum
- ILAC International Laboratory Accreditation Cooperation
- IEC International Electrotechnical Commission
- ISO International Organisation for Standardisation
- ITC International Trade Centre
- ITU International Telecommunications Union
- OIML Organisation Internationale de Métrologie Légale
- UNECE United Nations Commission for Europe
- UNIDO United Nations International Development Organisation
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.
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
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.
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.
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

ISO/IEC 17025:2005

5.6 Measurement traceability

5.6.1 General

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 used. The equipment of the laboratory shall have an established programme and procedure for calibrating apparatus. Such a programme should include providing, maintaining and training suitably skilled personnel, selecting and using equipment and test equipment to perform tests and calibrations.

NOTE Such a programme should include providing, maintaining and training suitably skilled personnel, selecting and using equipment and test equipment to perform tests and calibrations.

5.6.2 Specific requirements

5.6.2.1 Calibration

5.6.2.1.1 For calibration laboratories, the programme of calibrations shall be operated so as to ensure that calibrations and measurements are traceable to the International System of Units (SI) (Système International d'Unités (SI)). The calibration laboratory shall have an established programme and procedure for calibrating equipment. Such a programme should include providing, maintaining and training suitably skilled personnel, selecting and using equipment and test equipment to perform tests and calibrations.

A calibration laboratory establishes traceability of its own measurement standards and measuring instruments to the SI by means of an unbroken chain of calibrations or comparisons linking them to relevant primary standards of the SI units of measurement. The link to SI units may be achieved by reference to national measurement standards. National measurement standards may be primary standards, which are primary realizations of the SI units or agreed representations of SI units based on fundamental physical constants, or they may be secondary standards which are standards calibrated to these primary standards. When using external calibration services, traceability of the calibration services from laboratories that can demonstrate traceability. The calibration certificates issued by these laboratories shall demonstrate the calibration traceability of the SI units of measurement. The calibration certificate shall demonstrate the calibration traceability of the SI units of measurement. The calibration certificate shall demonstrate the calibration traceability of the SI units of measurement.

NOTE 1 Calibration laboratories fulfilling the requirements of this International Standard are considered to be competent. A calibration certificate bearing an accreditation body logo from a calibration laboratory accredited to this International Standard, for the calibration concerned, is sufficient evidence of traceability of the calibration data reported.

NOTE 2 Traceability to SI units of measurement may be achieved by reference to an appropriate primary standard (see VIM 1993, 5.4) or by reference to a natural constant, the values of which in terms of the relevant SI unit is known and recommended by the General Conference on Weights and Measures (CGPM) and the International Committee on Weights and Measures (CIPM).
Documentary standards - measurement
Accreditation – ILAC policy on metrological traceability of measurement results (ILAC P10)

- **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
ILAC Policy for Uncertainty in Calibration (ILAC P14)

ILAC P14:01/2013 ILAC Policy for Uncertainty in Calibration
This document sets out the requirements and guidelines for the estimation and statement of uncertainty in calibration and measurement.

.....
ILAC P14:01/2013 ILAC Policy for Uncertainty in Calibration

References

[1] EA-4/02:1999, Expressions of the Uncertainty of Measurements in Calibration (including supplement 1 to EA-4/02) (previously EAL-R2)
Conclusions

• The value of metrology isn’t easy for the everyday person to understand.....

• The metrology community needs mechanisms that help embed its principles and practices such that they are adopted (even if that adoption is often invisible)

• The international and national quality infrastructure plays a major role in ensuring good metrological practice is carried from the laboratory to the application

• At national level the relationship between the QI players is important

• The national and international quality infrastructure cooperates intensively

• Metrology is a major winner from the QI association
Thank you

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Acronyms are defined on slides that follow
### Acronyms used in this presentation

- **ACCSQ**: ASEAN Consultative Committee on Standards and Quality
- **AFRAC**: African Accreditation Cooperation
- **AFRIMETS**: Intra-Africa Metrology System
- **APLAC**: Asia Pacific Laboratory Accreditation Cooperation
- **APMP**: Asia Pacific Metrology Programme
- **ARSO**: African Organisation for Standardisation
- **BIPM**: International Bureau of Weights and Measures
- **BSI**: British Standards Institution
- **CAP**: Conformity Assessment Procedures
- **CEN**: European Committee for Standardization
- **CENELEC**: European Committee for Electrotechnical Standardization
- **CGPM**: International Conference for Weights and Measures
### Acronyms used in this presentation

- **CIPM MRA** | CIPM Mutual Recognition Arrangement
- **CMA** | Central Metrology Authority
- **CMC** | Calibration and Measurement Capability
- **COOMET** | Euro-Asian Cooperation of National Metrological Institutions
- **COPANT** | Pan-American Standards Commission
- **DCMAS** | Network on Metrology, Accreditation and Standardization for Developing Countries
- **EA** | European Cooperation for Accreditation
- **ETSI** | European Telecommunications Standards Institute
- **EU** | European Union
- **EURAMET** | European Association of National Metrology Institutes
- **EURO NCAP** | European New Car Assessment Programme
Acronyms used in this presentation

- GAC GCC Accreditation Center
- GCC Gulf Cooperation Council
- GSO GCC Standardization Organization
- GULFMET Gulf Association for Metrology
- GUM Guide to the Expression of Uncertainty in Measurement
- HACCP Hazard Analysis Critical Control Point
- IAAC Inter American Accreditation Cooperation
- IAF International Accreditation Forum
- IEC International Electrotechnical Commission
- IECEE CB IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components
- IFCC International Federation of Clinical Chemistry and Laboratory Medicine
Acronyms used in this presentation

- ILAC  International Laboratory Accreditation Cooperation
- ISO   International Organization for Standardization
- IUPAC International Union of Pure and Applied Chemistry
- IUPAP International Union of Pure and Applied Physics
- JCTLM Joint Committee for Traceability in Laboratory Medicine
- KCDB  BIPM key comparison database
- LDC   Least Developed Country
- MAA   OIML Mutual Acceptance Arrangement
- MoU   Memorandum of Understanding
- NAB   National Accreditation Body
- NMI   National Metrology Institute
- NQI   National Quality Infrastructure
**Acronyms used in this presentation**

- **NSB**  National Standards Body
- **OIML**  International Organization of Legal Metrology
- **PAC**  Pacific Accreditation Cooperation
- **PAQI**  Pan African Quality Infrastructure
- **PASC**  Pacific Area Standards Congress
- **QI**  Quality Infrastructure
- **SI**  International System of Units
### Acronyms used in this presentation

- **SIM**  Inter-American Metrology System
- **TBT**  Technical Barriers to Trade
- **UNIDO**  United Nations Industrial Development Organization
- **VIM**  International Vocabulary of Metrology
- **WG**  Working Group
- **WTO**  World Trade Organization