




Consultative Committee for Units

Joachim Ullrich, CCU President

November 2022

A large, vibrant graphic on the right side of the slide. It consists of numerous concentric, slightly offset circular lines in a rainbow color palette (red, orange, yellow, green, blue, purple). These lines spiral inward, creating a sense of depth and movement. In the center of this spiral, the text 'Working together to promote and advance the global comparability of measurements' is written in a white, sans-serif font.


Working together to
promote and advance
the global comparability
of measurements



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A decorative graphic on the right side of the slide, consisting of numerous concentric, overlapping arcs in a rainbow color palette (red, orange, yellow, green, blue, purple). The arcs are of varying lengths and are arranged in a way that they appear to spiral inward towards the center of the slide.

27^e réunion de la
Conférence générale
des poids et mesures

Overview



1st meeting of the CCU (1967)

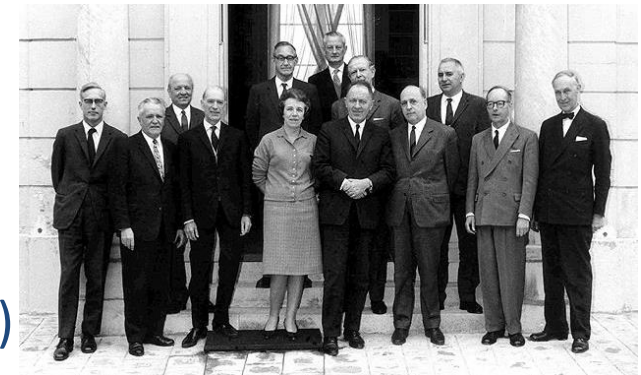
Overview



24th meeting of the CCU in October 2019. The 25th meeting in 2021 was held on-line.



1st meeting of the CCU (1967)



Overview



Members of the CCU

- 13 National Metrology Institutes
- 3 Personal / Honorary Members
- 1 Ex-officio Member

+ INRIM (Italy)

+ NSC IM (Ukraine)

Liaisons of the CCU

- 4 International Unions
- 5 International Commissions & Committees
- 2 Intergovernmental Organizations or International Bodies

+ International Mathematical Union, IMU

Overview

➡ Providing a global forum for progressing the state-of-the art

→ CCU is the only global forum for units

➡ Facilitating dialogue between NMIs and all stakeholders

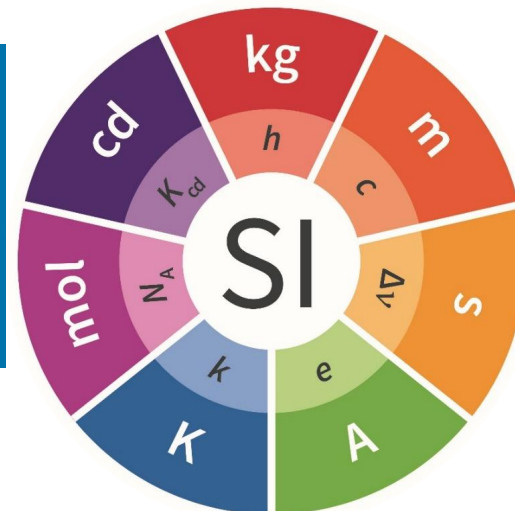
→ We always seek international consensus

➡ Enabling global comparability of measurements

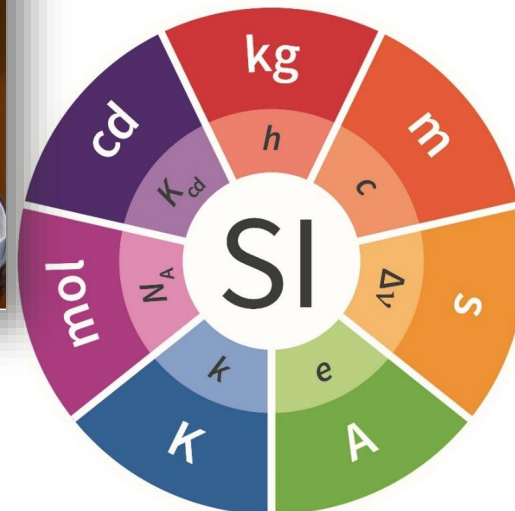
→ provide advice about units of measurement

→ develop the International System of Units

→ prepare the *SI Brochure*

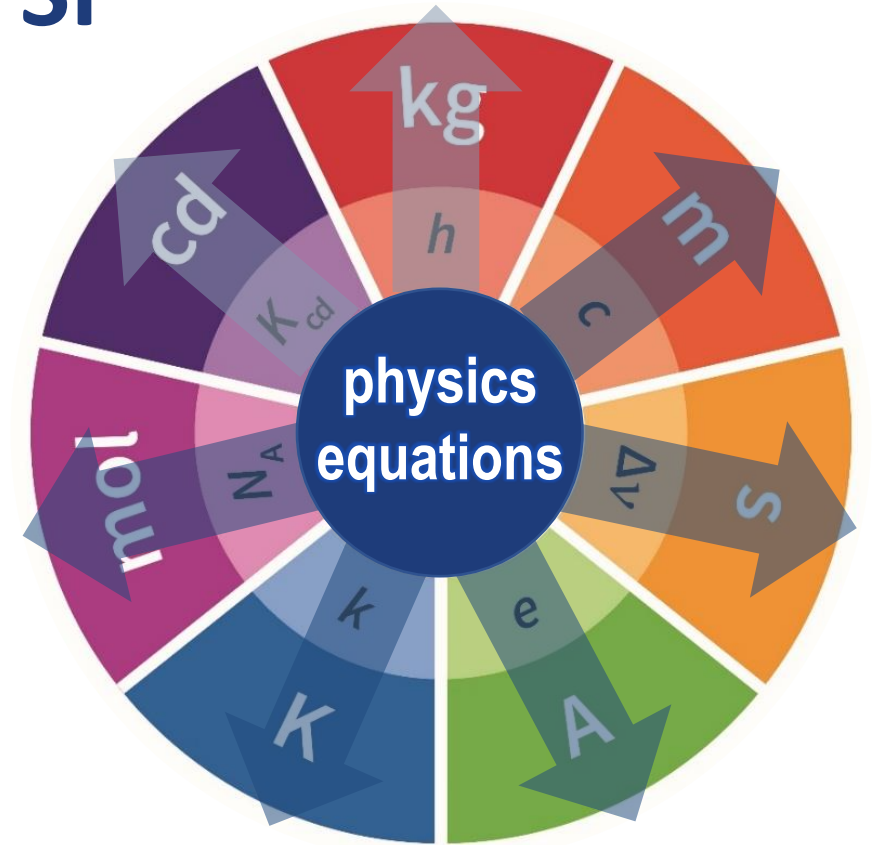
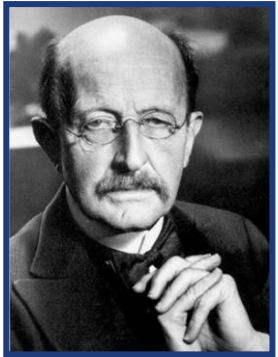


The International System of Units, SI



The International System of Units, SI

Hyperfine transition ^{133}Cs : $\Delta\nu = 9\,192\,631\,770\text{ Hz}$
Speed of light: $c = 299\,792\,458\text{ m/s}$
Planck constant: $h = 6.626\,070\,15 \times 10^{-34}\text{ J s}$
Elementary charge: $e = 1.602\,176\,634 \times 10^{-19}\text{ C}$
Boltzmann constant: $k = 1.380\,649 \times 10^{-23}\text{ J/K}$
Avogadro constant: $N_A = 6.022\,140\,76 \times 10^{23}\text{ mol}^{-1}$
Luminous efficacy: $K_{\text{cd}} = 683\text{ lm/W}$



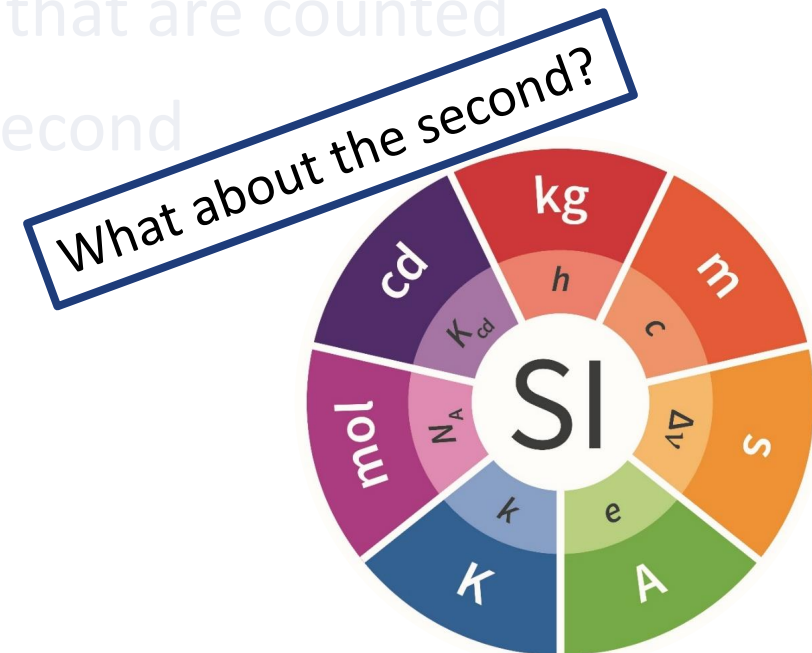
...based on our present understanding of nature
...valid for all times and civilisations
...throughout the universe

What about the second?

The International System of Units, SI

Current and Future Activities

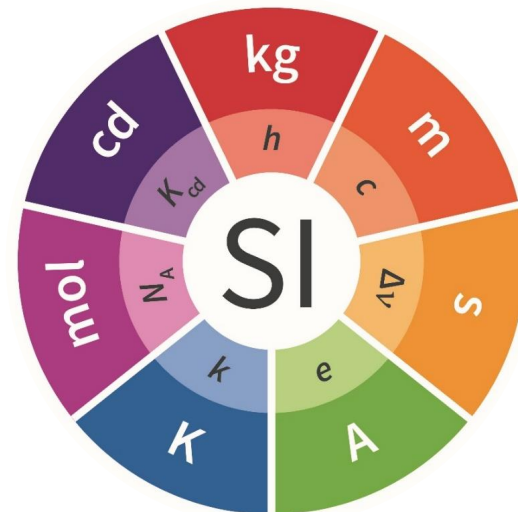
- A Questionnaire about the Implementation of the SI
- Draft Resolution C: On the Extension of the Range of SI Prefixes
- CCU TG – ADQSIB: Dimensionless Quantities in the SI Brochure
- CCU / CCQM: Workshop on Quantities that are counted
- CCU / CCTF: The Redefinition of the Second
- CCU WG – CMT: Core Metrological Terms
- CCU WG – Strategy: Key Scientific Challenges



The International System of Units, SI

A Questionnaire about the Implementation of the SI

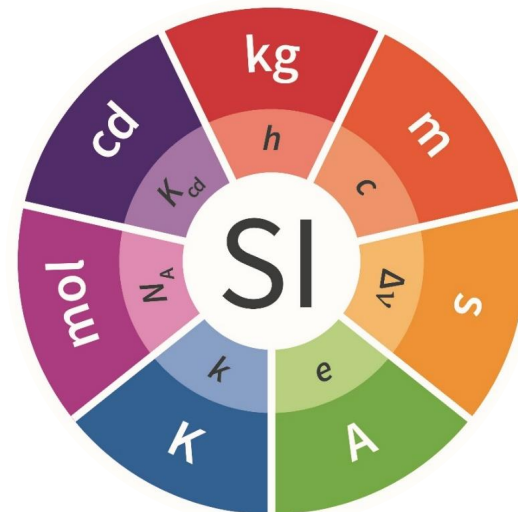
- For NMIs, Liaison Organisations and Teaching Organizations
- Sent in March 2021 with a Deadline for Replies on 31 May 2021
- Responses: 18 NMIs,
7 Liaison Organisations,
5 Schools, 12 Universities, 1 Ministry



The International System of Units, SI

A Questionnaire about the Implementation of the SI

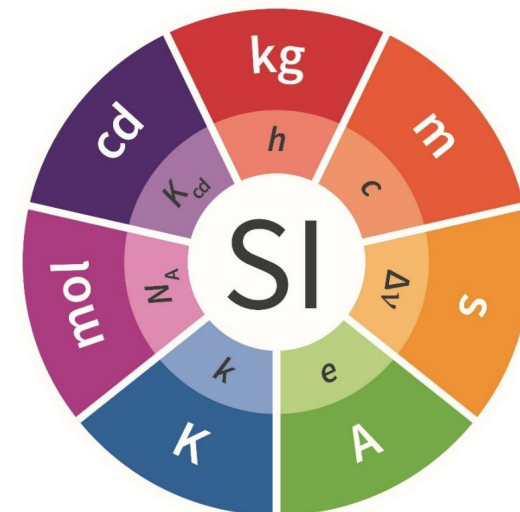
- ➔ No difficulties in the implementation of the revised SI were reported
- ➔ A number of possibilities for innovative technologies were mentioned
- ➔ Liaison organizations felt in general sufficiently well informed



The International System of Units, SI

Current and Future Activities

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The International System of Units, SI

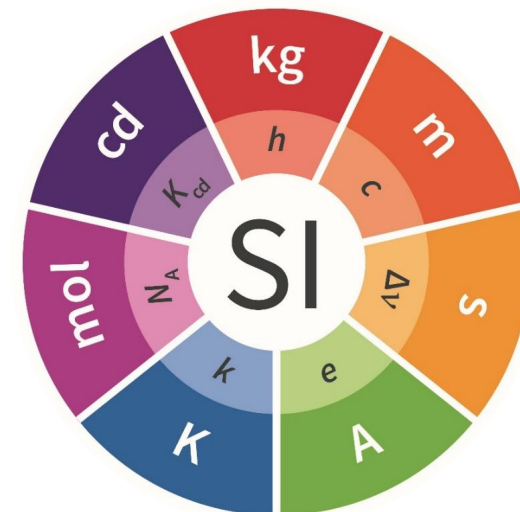
Draft Resolution C: On the Extension of the Range of SI Prefixes

Dynamic developments in science and computer-technology

decides to add to the list of SI prefixes to be used for multiples and submultiples of units the following prefixes:

Multiplying factor	Name	Symbol
10^{27}	ronna	R
10^{-27}	ronto	r
10^{30}	quetta	Q
10^{-30}	quecto	q

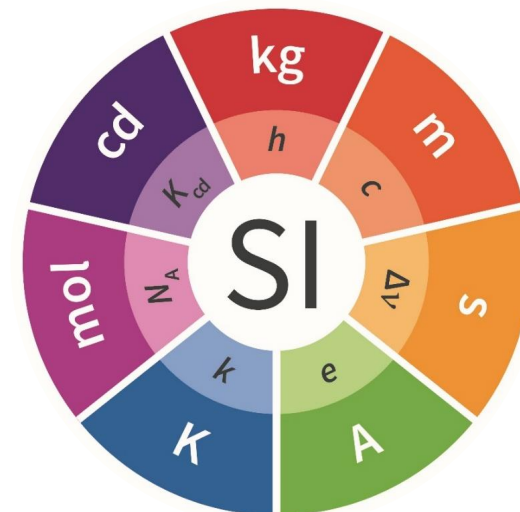
➡ **Richard Brown**



The International System of Units, SI

Current and Future Activities

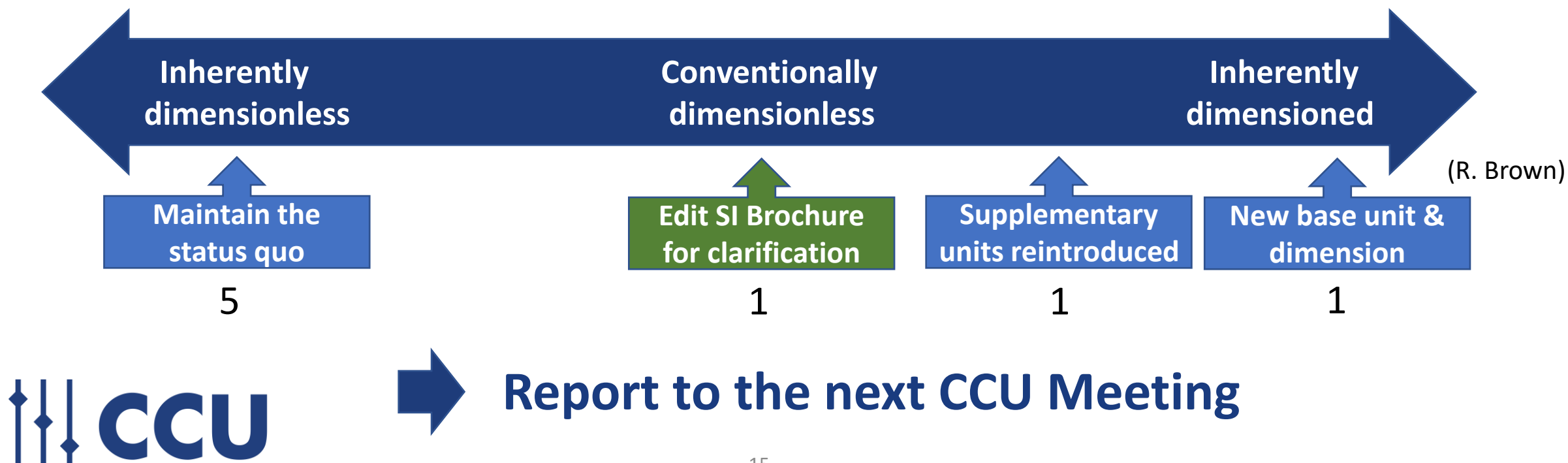
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The International System of Units, SI

TG – ADQSIB: Dimensionless Quantities in the SI Brochure

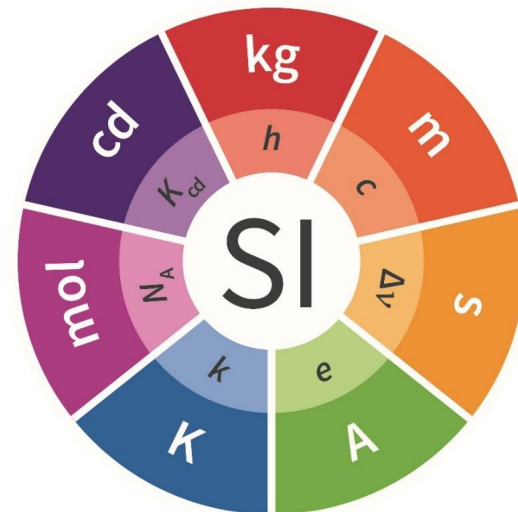
- E.g. Concentration (CO_2 in Air) = $0.6 \text{ mg/g} = 0.6/1000 = 0.06 \%$
- E.g. Angle: $1 \text{ rad} = 1 \text{ m} / 1 \text{ m} = 1$



The International System of Units, SI

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The International System of Units, SI

Joint CCU/CCQM Workshop on Quantities that are Counted

➔ to achieve a common understanding of counting within the SI

Session 1 Concepts and theoretical aspects

Welcome and background to the workshop	Pavel Neyezhmakov (NSC-IM)	15 min
What questions is the workshop addressing?	Bernd Güttler (PTB)	15 min
Concepts of continuous quantities & countable aggregates and nomenclature	Charles Ehrlich (NIST)	15 min
Quantities with the unit one	Peter Blattner (METAS) / TBC	15 min
Counting & why it is different from amount of substance	Richard Brown (NPL)	15 min
Panel Q&A / Discussion	All	45 min

Session 2 Counting entities (case studies from electricity, mass, chemistry and biology)

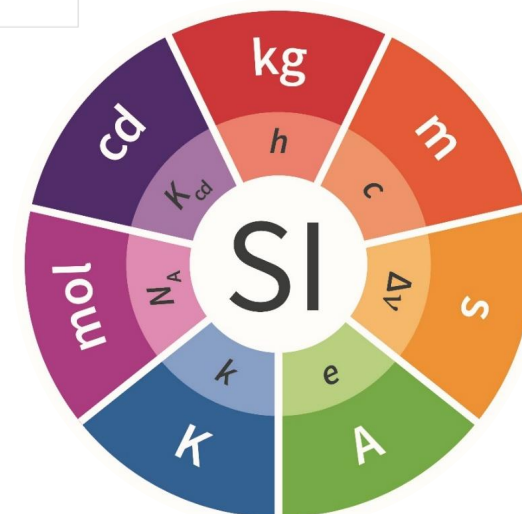
Introduction to the case studies	Richard Brown (NPL)	5 min
Counting electrons (CCEM) (nom. Gert Rietfeld)	Stephen Giblin (NPL) / Hans Werner Schumacher (PTB) / TBC	15 min
Counting ^{28}Si in a silicon sphere (CCQM, CCM)	Olaf Rienitz (PTB)	15 min
Digital PCR	Inchul YANG (KRISS) / TBC	15 min
Counting cells	Jonathan Campbell LGC	15 min
Counting particles in air	Konstantina Vasilatou (METAS)	15 min
Panel Q&A / Discussion	All	40 min

Session 3 Counting processes & other phenomena (case studies from radioactivity to light)

Introduction to the case studies	Bernd Güttler (PTB)	5 min
CCRI (nom. Martyn Sené)	Ryan Fitzgerald (NIST)	15 min
CCL	Alessandro Balsamo (INRIM)	15 min
CCTF	Elizabeth Donley (NIST)	15 min
CCPR (nom. Maria Luisa Rastello)	Stefan Kück (PTB)	15 min
Discussion & concluding remarks: how should the metrology community respond and next steps	Sang-Ryoul Park (KRISS) & Joachim Ullrich (PTB)	55 min



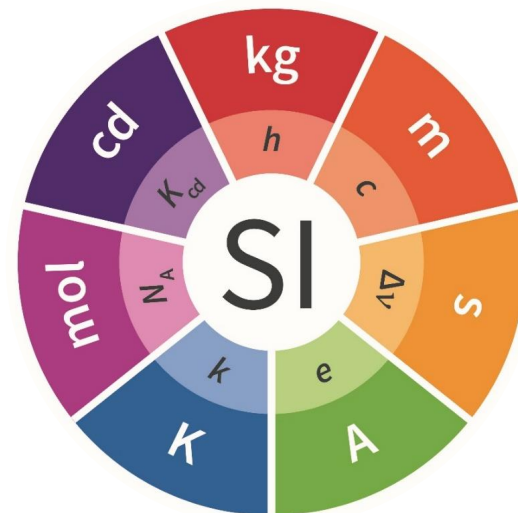
In final
planning stage



The International System of Units, SI

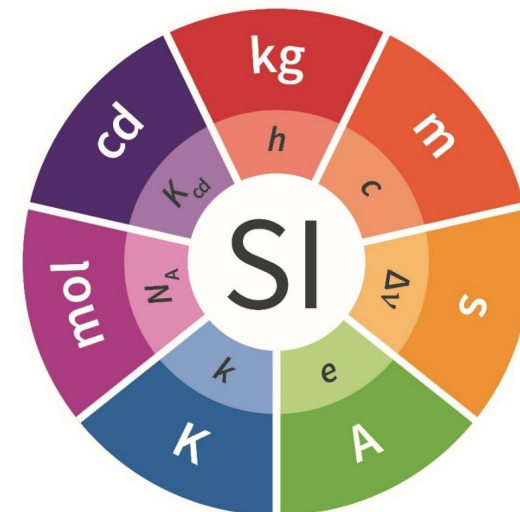
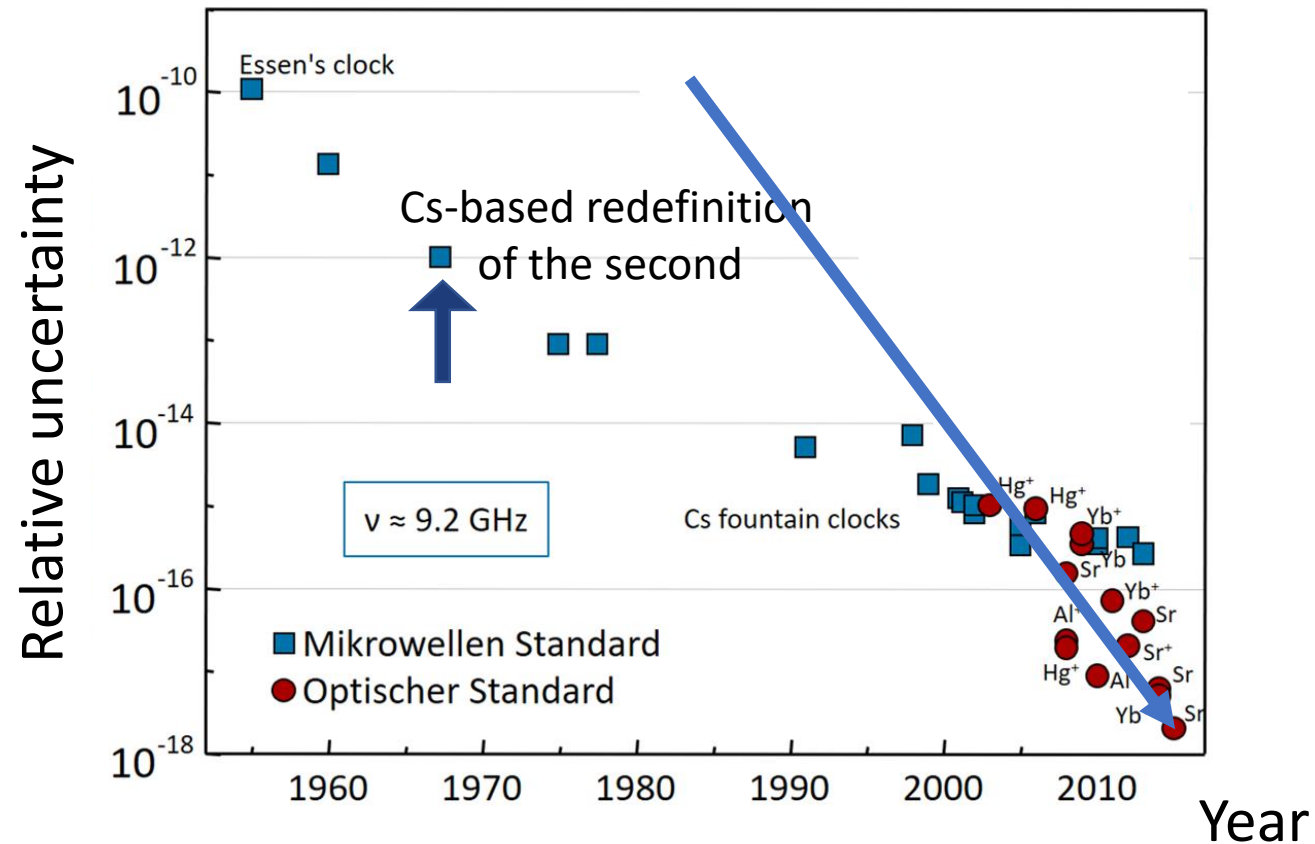
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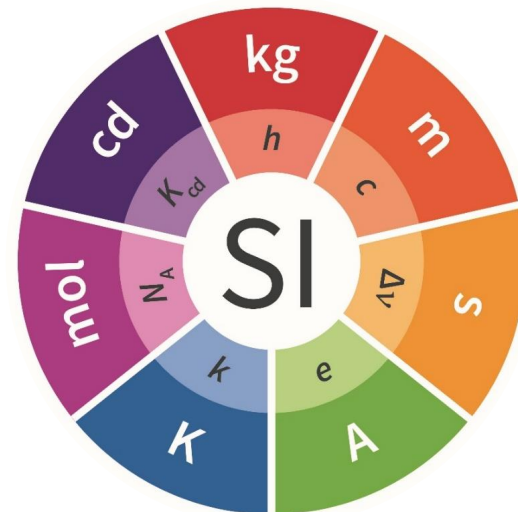
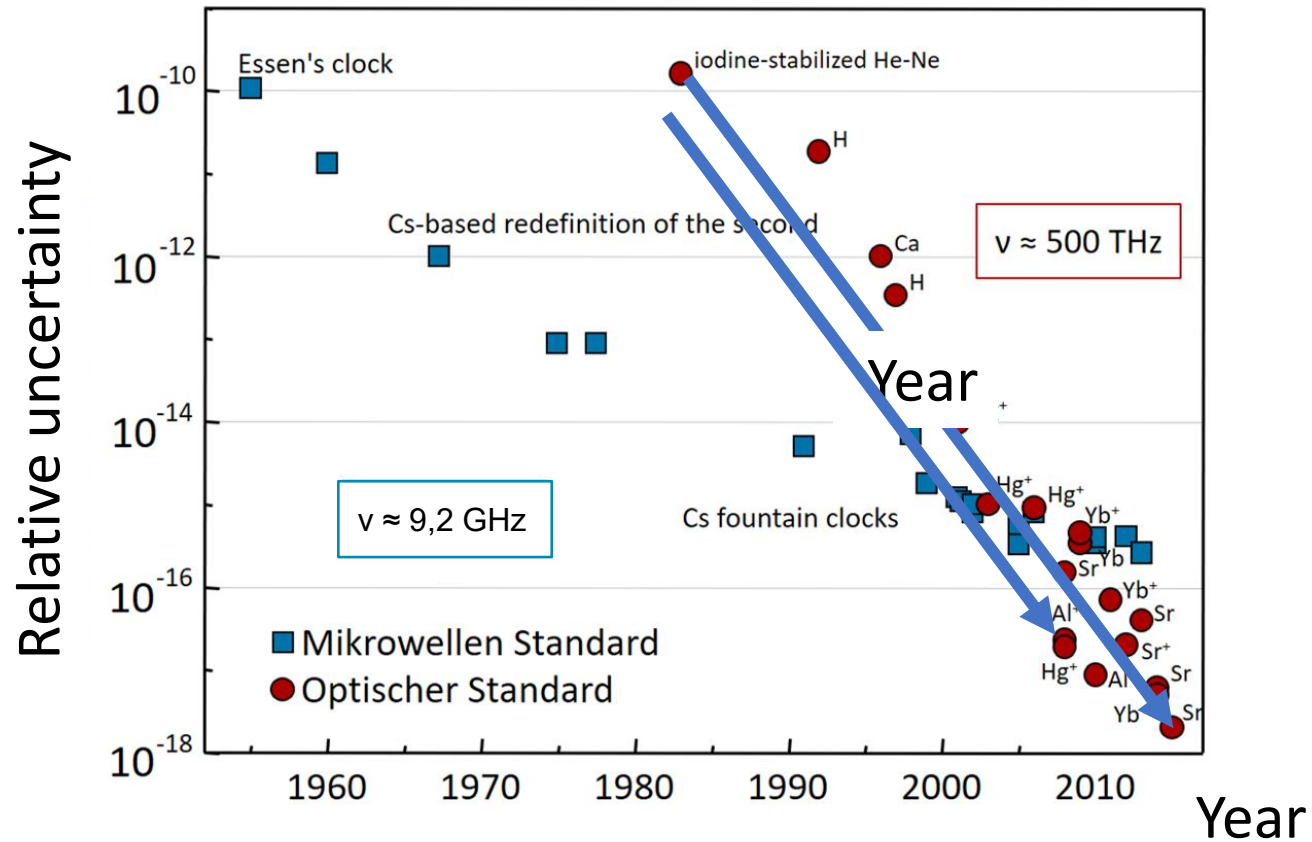
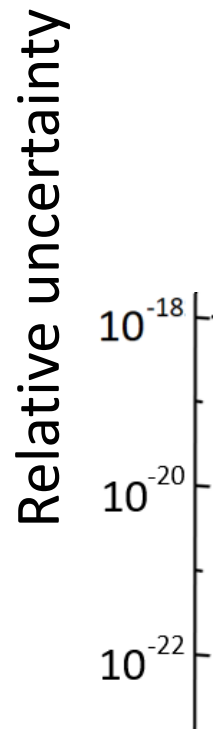
The International System of Units, SI

With CCTF: The Redefinition of the Second



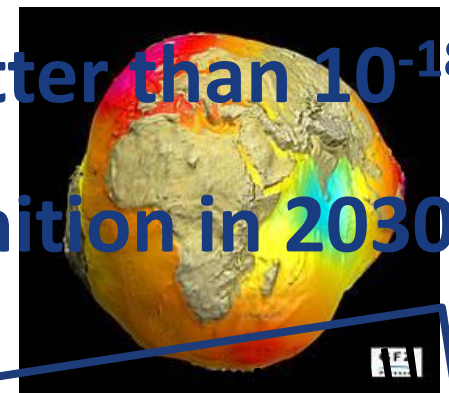
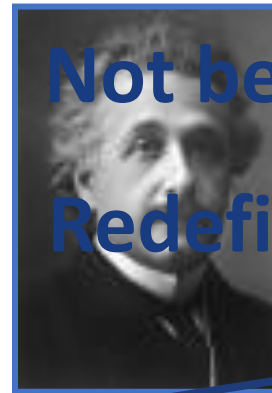
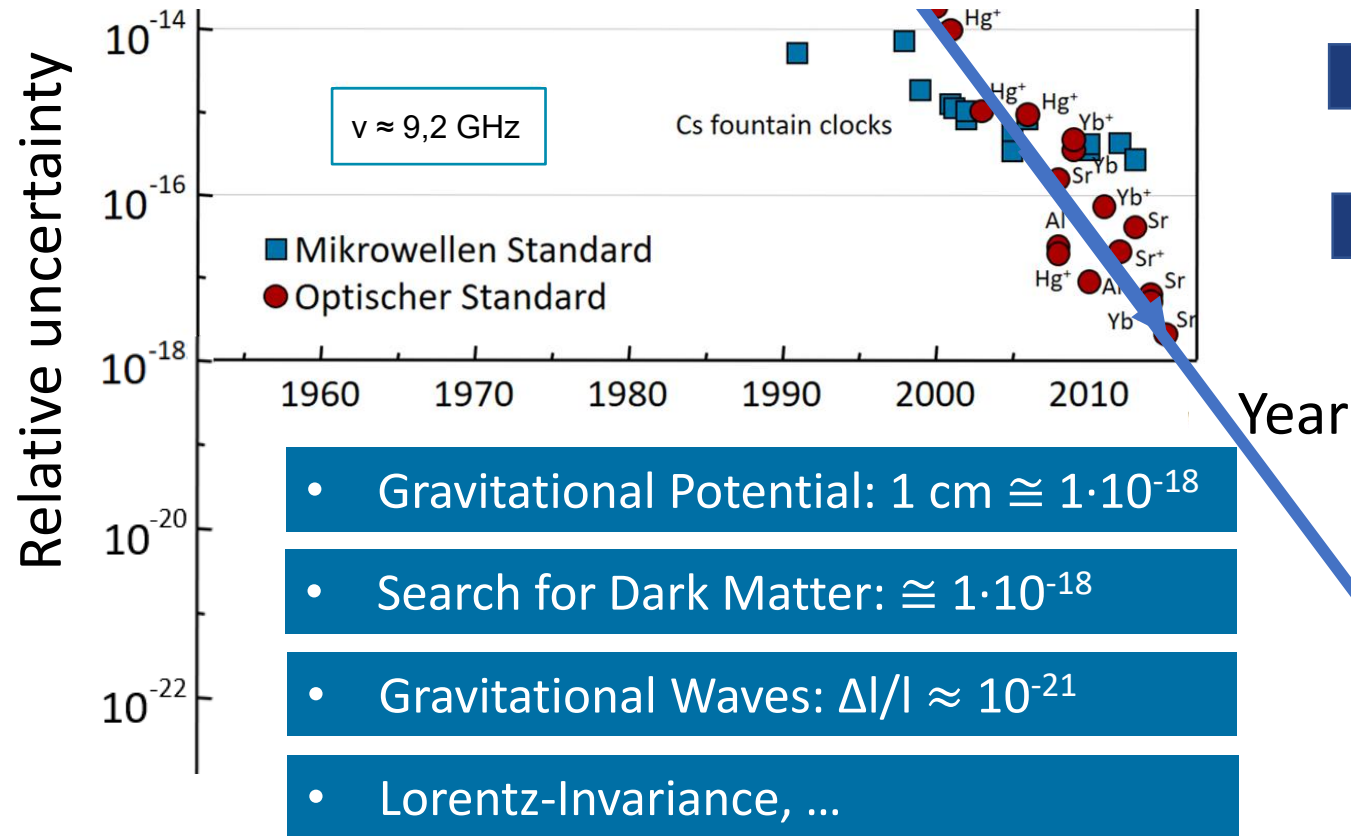
The International System of Units, SI

With CCTF: The Redefinition of the Second

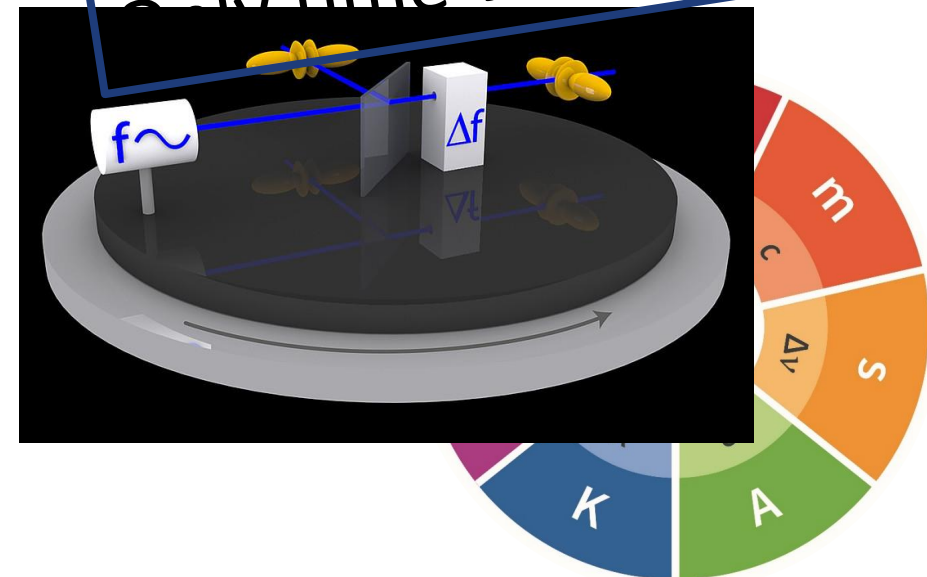


The International System of Units, SI

With CCTF: The Redefinition of the Second



Not better than 10^{-18}
Redefinition in 2030...



The International System of Units, SI

With CCTF: The Redefinition of the Second

Agenda for the BIPM Workshop on “Advanced Time and Frequency Transfer: the ultimate frontier for remote comparison methods”

Venue: Pavillon du Mail, BIPM, Sèvres, France.

Start: Thursday 10 October 2019 at 09:00

09:00 - 09:05 Opening address of the Workshop

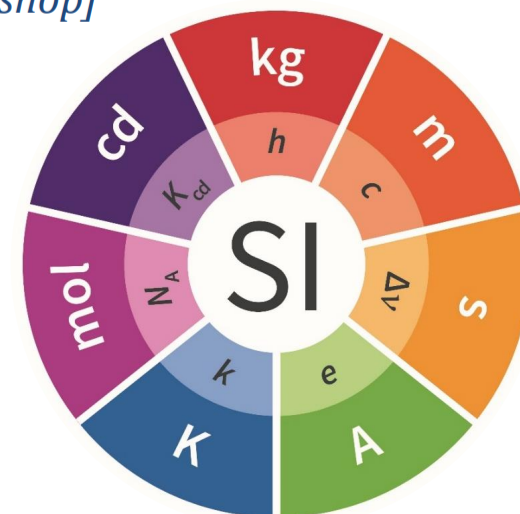
[Prof. Joachim Ullrich (PTB) and Dr Davide Calonico (INRIM), Chairs of the Workshop]

09:05 - 09:15 Introduction on CCTF WGATFT activity

[Dr Davide Calonico, INRIM (Italy)]



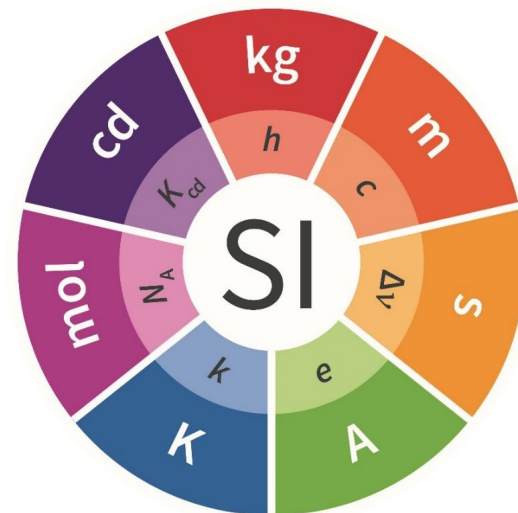
Encourage and monitor research on optical transitions whose frequencies could be candidates for redefining the SI second.



The International System of Units, SI

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The International System of Units, SI

WG – CMT: Core Metrological Terms

... quantity, unit, quantity value,...

Decision CIPM/108-25

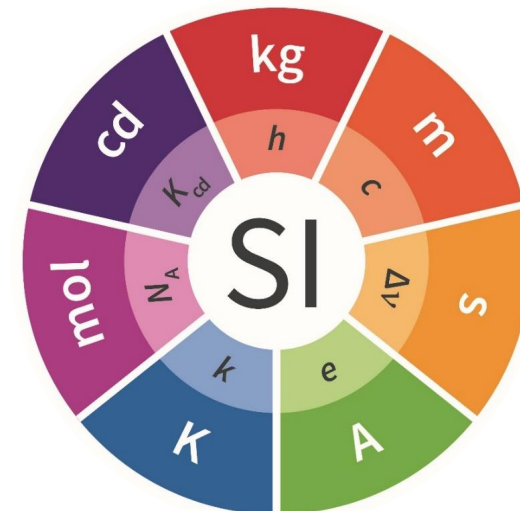
The CIPM approved the establishment of the CCU Working Group on Core Metrological Terms (CMT) and endorsed the terms of reference suggested by the CCU President and as communicated previously to the CCU.

The CIPM welcomed the fact that the Chair of the CCU Working Group on Core Metrological Terms (CMT) is also the CIPM Representative at the JCGM.



The CIPM takes responsibility through its CCU

- ➡ A structured input into the JCGM
- ➡ 5 meetings until now



The International System of Units, SI

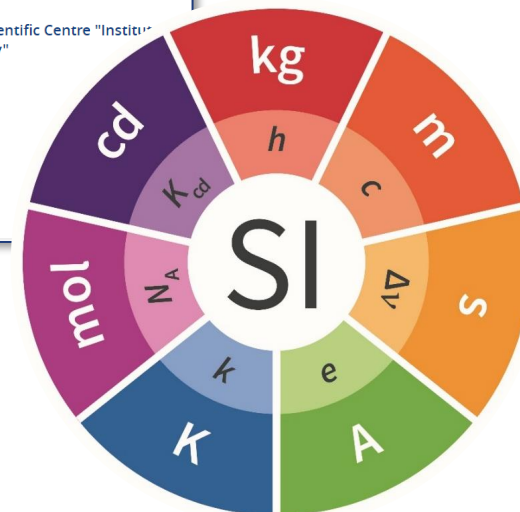
WG – CMT: Core Metrological Terms

Terms of reference

The Terms of reference of the CCU-WG-CMT are the following

- Identify core metrological terms that enter into CGPM Resolutions and national legislation, and which are therefore in the interest of Member States.
- Propose definitions/explanations for these core metrological terms:
 - Considering translation into other languages, in particular into French,
 - Considering requirements concerning machine readability of these terms,
 - Aiming at finding consensus definitions in particular with OIML and involving other NGO stakeholders.
- Ensure proper representation of these findings in the JCGM WG2 (VIM) upon approval by the CIPM.
- Make proposals to ensure proper and harmonized representation of CIPM-approved statements in relevant Liaison Organization committees.

Members	
Centro Español de Metrología → CEM Madrid	Federal Agency on Technical Regulating and Metrology → Rosstandart Moscow
Federal Institute of Metrology METAS → METAS Bern-Wabern	Laboratoire National de Métrologie et d'Essais → LNE Paris
National Institute of Metrological Research/Istituto Nazionale di Ricerca Metrologica → INRIM Turin	National Institute of Standards and Technology → NIST Gaithersburg
National Metrology Institute of Japan, AIST → NMIJ/AIST Tsukuba	National Physical Laboratory → NPL Teddington
National Research Council of Canada → NRC Ottawa	National Scientific Centre "Institut of Metrology" → NSC IM Kharkiv
Physikalisch-Technische Bundesanstalt → PTB Braunschweig	

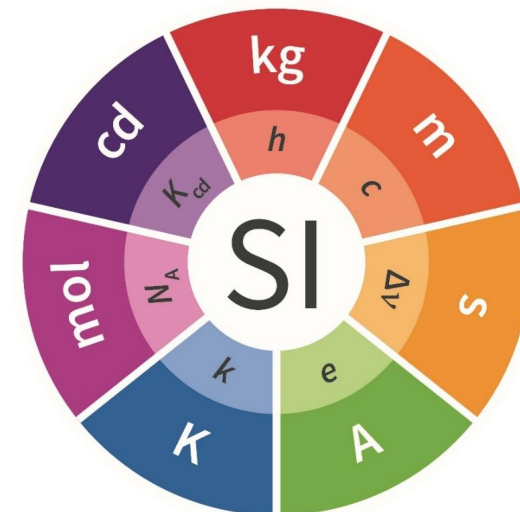


+ experts in axiomatic mathematics,
linguistics and digitalization

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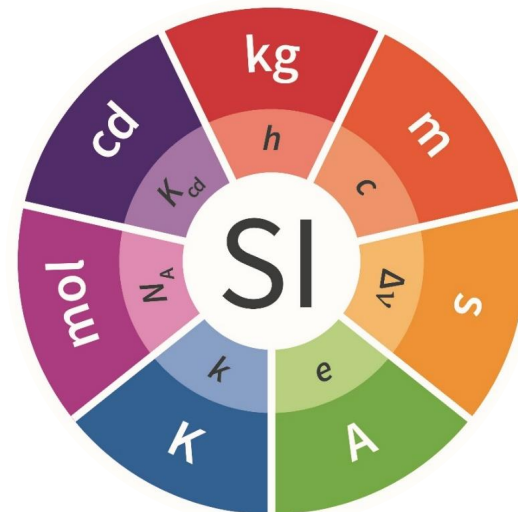


The International System of Units, SI

CCU WG – Strategy: Key Scientific Challenges

How can the CIPM foster and promote international cooperation

- in response to the implementation of the revised SI
- towards a possible future revision of the SI
- in response of primary metrology outside the NMIs
- in response of the science of Systems Metrology

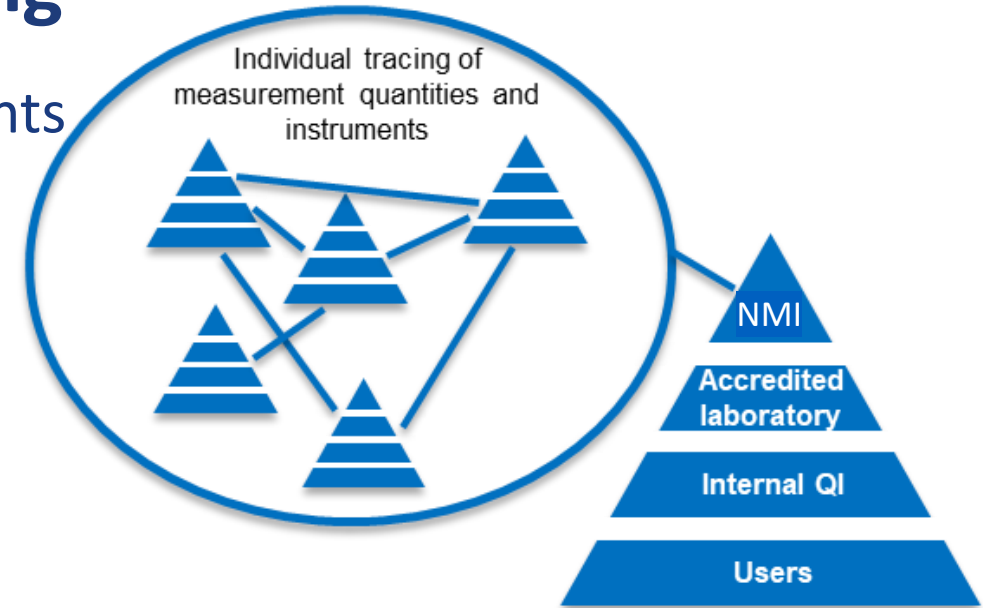


The International System of Units, SI

Systems Metrology: Autonomous Driving

Metrologically sound testing of all relevant components

- Sensing (up to 400 sensors)
- Communication, e. g., using 5G or 6G
- Simulations (often AI-based)
- Influences of other road users

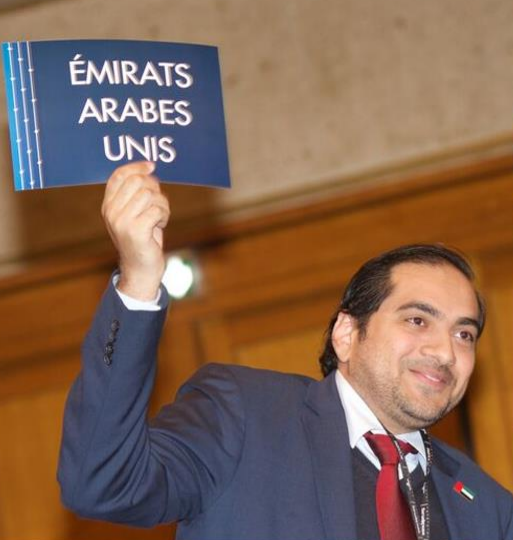


Challenges of systems metrology

- ***What does an algorithm learn*** from a given situation and how will it respond in the future?
- ***How does the same algorithm react*** if individual sensors measure with reduced accuracy?

+ Personalized Medicine

+ City of the Future: Smart Homes, ~Energy, ~Industry, ~Mobility,...



Nobel Prize!?

Science bridges culture!

A historic event!