

Consultative Committee for Units (CCU)

President: Prof. Joachim Ullrich

Executive Secretary: Dr Estefanía de Mirandés

1. Executive summary

The CCU, created in 1964, provides advice to the International Committee for Weights and Measures (CIPM) in all matters concerning the central goal and most important task of the Metre Convention, namely to establish, maintain and disseminate a state-of-the-art International System of Units, the SI, to Member States of the BIPM and Associate States and Economies of the General Conference on Weights and Measures (CGPM). As of now this is a total of about 100 countries representing more than 97 % of the world's economic power.

To fulfil its task, the CCU seeks advice from and liaises with its members and stakeholders, international associations, commissions and committees as well as intergovernmental organizations and international bodies, and stays in close collaboration with all related Consultative Committees (CCs) and the National Metrology Institutes (NMIs).

The most recent challenge of the CCU has been to guide, coordinate and scientifically underpin the envisaged fundamental change of the SI towards the “Revised SI”. Rather than still partly relying on artefacts, material properties or idealized definitions to define the units, the revised system is expected to be based on fixing the numerical values of a coherent set of “Defining Constants” and establishing procedures that realize the units, the *mises en pratique* (MeP).

Since the adoption by the 24th meeting of the CGPM (2011) of Resolution 1 “On the possible future revision of the International System of Units, the SI”, the CCU has focused its activities on the preparation for the redefinition, especially by providing a draft of the 9th Edition of the SI Brochure, the most widely used publication of the BIPM. The final draft is now completed and publicly available. Moreover, an infographic for the “Revised SI” has been designed by the CCU and a logo by a CIPM Task group, headed by the CCU President, and measures for informing the wider public about the redefinition have been taken.

A “Strategy document for the CCU for the period 2013 to 2023” was prepared in February 2014, and was reviewed and improved in the CCU meeting in June 2016. The CCU strategy will be fully revised after the adoption of the revision on the SI, in the CCU meeting that will take place in October 2019.

Responding to a request for guidance, the CCU Working Group on “Angles and Dimensionless Quantities” was created in June 2014 and met for the first time in February 2015. The discussions focused on the pertinence of adding the radian as a new base unit of the SI and on the treatment of so-called “dimensionless” quantities in the draft of the 9th edition of the SI Brochure. After many discussions, the group could not come to a consensus on any of these issues and therefore it was decided that in the 9th edition of the SI Brochure the treatment of the radian and of dimensionless quantities should be kept the same as in the 8th edition, in compliance with CGPM resolutions in force.

2. Scope of the CCU

The CCU, created in 1964, provides advice to the CIPM in all matters concerning the central goal and most important task of the Metre Convention, namely to establish, maintain and disseminate a state-of-the-art International System of Units, the SI, to Member States of the BIPM and Associate States and Economies of the General Conference on Weights and Measures (CGPM). As of now this is a total of about 100 countries representing more than 97 % of the world's economic power.

The work of the CCU is concerned with matters related to:

- the development and improvement of the International System of Units (SI),
- providing advice to the CIPM about units of measurement in general,
- providing information and advice on units and their use beyond the CIPM to a wide range of international bodies, associations, commissions and committees as well as individuals who approach the BIPM seeking such information.

To fulfil its task, the CCU seeks advice from and liaises with its members and stakeholders, international associations, commissions and committees as well as intergovernmental organizations and international bodies, and stays in close collaboration with all related Consultative Committees (CCs) and National Metrology Institutes (NMIs).

The CCU is responsible for the preparation of successive editions of the SI Brochure, including the “Concise Summary of the SI” and any other summaries relevant to metrology institutes, industry, universities and school teachers as well as to the general public. The SI Brochure, now in its 8th Edition (dated 2006), is the most important and widely used publication of the BIPM. It is the result of work by many people, both inside and outside the BIPM, and its production requires a high level of scientific knowledge and experience. Every care is taken with preparing the text, not only in the accuracy of the meaning but also because it is translated into many other languages as well as being used by people whose mother tongue is neither French nor English. During the past years, the CCU has been preparing the 9th Edition of the SI Brochure, which incorporates the revised definitions of the SI. If, as expected, the new definitions are approved by the 26th CGPM in November 2018, this Brochure will be published on 20 May 2019, the day of the official implementation of the revised SI.

3. Strategy

According to the scope of the CCU to provide advice to the CIPM in all matters concerning measurement units in general and the SI in particular, it has in recent years developed a strategy for redefining the base units to cope with the advancing needs of industry, society and science.

This resulted in the development of the “Revised SI” that is now based on two key elements, namely:

- (i) fixing the numerical values of a consistent and coherent set of “Defining Constants” and
- (ii) establishing procedures to realize the units: the *mises en pratique*.

The revision, based on Resolution 1 of the 24th CGPM (2011) and expected to be approved in November 2018 by the 26th CGPM, includes new definitions of the kilogram, the ampere, the kelvin and the mole. The main challenge faced by the CCU over the past few years has been to

guide, coordinate and scientifically underpin the fundamental change of the SI to the “Revised SI”.

Strategic guiding principles of this effort have been:

- I. Ensuing continuity and practicability.
- II. Ensuring coherence, stability and a sound scientific foundation.

For example, the uncertainty limits of the Kibble balances and the silicon sphere experiments and their consistency as formulated by the Consultative Committee for Mass and Related Quantities (CCM) have been key requirements for the decision to redefine the SI. Both experiments have been used to determine Planck’s constant h , or equivalently, establish the relation between the kilogram and the defining constant h . At the same time their consistency along with results of experiments on the so-called ‘quantum metrological triangle’ guarantee the consistency of realizations of the ampere, and thus, of the electrical units, based on utilizing the von Klitzing and the Josephson constants.

- III. Enabling the realization of the units so that the advancing needs of industry, society and science are always satisfied at the highest technological level.

Here, the new approach offers the following advantages:

- Many SI units can be realized directly from an appropriate combination of the defining constants, currently with no difference between units called base units or derived units, although the concept of base units will be kept for historical and practical reasons.
- A unit may be realized via fundamentally different experiments (for example on a macroscopic level the kilogram might be realized by a Kibble balance and silicon spheres, and on a microscopic level by photon recoil or De-Broglie wavelength measurements), which enables key comparisons with no or little correlation.
- The units are defined and may be realized on the entire scale and not only, such as for the present kelvin, at just two fixed points, requiring interpolations and extrapolations.
- Any unit can be realized, in principle, with ever-increasing accuracy in the future as science and technology evolves, since the definitions do not include *mises en pratique*.

In the future, new suggestions for realizations of units in terms of the Defining Constants will emerge along with further proposals for the *mises en pratique*. The CCU will monitor these developments, take care of the consistency of the overall system and provide scientific advice to the CIPM in close coordination with the involved CCs.

A detailed roadmap for redefining the kilogram by 2018 was worked out by the CCM together with the CCU, and was approved by the CIPM at its 103rd meeting in March 2014. It included distinct requirements on the quality of the experimental data requested for fixing the numerical value of the Planck constant. Similar requirements have been stated by the other CCs involved. Over recent years, significant progress has been achieved and this has allowed the required criteria to be met such that a proposal for adopting the new definitions has been submitted to the 26th CGPM and is expected to be approved in November 2018.

In the years directly after redefinition, much public attention might still be expected and the CCU along with its President will further work towards providing explanations and increasing general acceptance.

The strategy of the CCU will be revised in the next CCU meeting, in October 2019, once the revision of the SI would have taken place and been fully implemented. A new CCU Strategy Working Group has been established for this purpose. Among the new tasks that the CCU is

expected to embrace, there is the possible future redefinition of the second whose development will be monitored in close collaboration with the Consultative Committee for Time and Frequency (CCTF).

4. Activities and achievements since the last meeting of the CGPM

4.1. Main activities

The most important activity of the CCU in recent years has been the preparation of the “Revised SI”. This is the subject of Draft Resolution 1 of the 26th CGPM (2018)

The CCU has accomplished the following:

- The draft of the 9th SI Brochure describing the “Revised SI” has been finalized and has been made available on the open BIPM website. During the past years, the draft Brochure has been available for comments both from CCU members, from NMIs and from the widest possible audience which has been able to follow the developments of the draft Brochure from the open BIPM webpages. All comments to the consecutive versions were collected and taken into account for the final version.
- In January 2014, the President of the CCU re-established the “Drafting Team for the 9th SI Brochure”, which had been set up at the 21st meeting of the CCU in June 2013. The new “Drafting Team” met in June 2015 in order to review the comments received on the draft first three chapters of the 9th SI Brochure. The subsequent version of the Brochure was drafted by the Editing Team and was opened to comments. The draft Brochure reached its final stage in November 2018. The translation into French is being completed.
- A CCU Working Group was created with the task of reviewing the “Angles and dimensionless quantities in the SI”, for which some guidance on the use of units and in expressing values of quantities was requested. The terms of reference, membership and chairmanship of this body were approved by the CCU. The first meeting of the Working Group was held at the BIPM in February 2015 with the aim of developing advice for the presentation of units for so-called “dimensionless” quantities, including counting quantities and to discuss the pertinence of including the radian as a SI base unit. The group had intense discussions on all these topics but it was not possible to reach consensus on any of the issues addressed. As a consequence, in the subsequent CCU meeting, it was decided not to make any modifications in the 9th edition of the SI Brochure to the subjects related to angles and dimensionless quantities. The text of the new Brochure is therefore fully compliant with all past CGPM resolutions that addressed the issue of the radian and dimensionless quantities.
- The President, who chairs the CIPM Task Group on the Promotion of the SI, has led the work of the Task group on the production of a logo for the “Revised SI”. This SI logo has been now officially approved and is publicly downloadable from the BIPM open webpages.
- The CCU strategy document, which has been in force since February 2014, is being revised by the newly established CCU Strategy Working group to clarify the mission of the CCU once the revision of the SI is approved and implemented. The new strategy document will be approved by the CCU on October 2019. One of the main tasks the CCU is expected to take in is the monitoring of the advances towards a future redefinition of the second. This work will be led by the CCTF and the steps of the process have already been defined in a CCTF roadmap, which foresees at present a possible adoption of the redefinition of the second by the CGPM in 2030.

4.2. Challenges and difficulties

One of the challenges the CCU has had to face is linked to the implementation of the “Revised SI”. Convincing the communities of the need to depart from artefacts and prototypes has been a demanding task. In this respect, the CCU will continue to provide advice to ensure a smooth transition from the present to the “Revised SI”.

Following a decision of the CIPM, the CCU and other CCs have revised their membership and relationship with organizations in *liaison* in 2018. The CCU wishes to keep working closely with all its members and liaisons involving all of them and their stakeholders in the discussions to attain consensus and general support.

5. Outlook in the short and long term

In the short term, the 9th edition of the SI Brochure and the Concise Summary will be published, both in English and French, and officially adopted on 20 May 2019, the day of the implementation of the revised SI.

The CCU will closely follow the transition to the revised SI to ensure a smooth passage.

In the long term, efforts will be focused on monitoring the developments towards the future expected redefinition of the second. Moreover, scientific advances that might have an effect on the realization of the SI units will be monitored and emphasis will be given to core definitions in the VIM, directly relating to the revised SI, like definitions of the terms “unit”, “measurement”, “traceability” and others.

Annex: CCU Data

CCU set up in 1964

President: J. Ullrich

Executive secretary: E. de Mirandés

Membership:

Since 2018: 11 members, 10 international organizations in *liaison* and no observers

List of CCU members:

<https://www.bipm.org/en/committees/cc/ccu/members-cc.html>

Meetings since the 25th CGPM meeting:

15-16 June 2016, 5-6 September 2017

Full reports of the CCU meetings:

<https://www.bipm.org/cc/AllowedDocuments.jsp>
<https://www.bipm.org/cc/AllowedDocuments.jsp>

One Working Group:
“Angles and dimensionless quantities in the SI”

<https://www.bipm.org/en/committees/cc/wg/wgadq.html>

