

Report from the CCTF Status of the planned redefinition of the second

Noel Dimarcq, Patrizia Tavella



CCTF HOT TOPICS

The **Consultative Committee on Time and Frequency** is concentrating on 4 hot topics for which task groups have been created in 2020 under the CCTF Strategic Planning WG coordination

1. Task Force on Updating the Roadmap towards the redefinition of the SI second:

- A. Request from user communities, NMIs and Liaisons
- B. Atomic frequency standards, and possible redefinition approaches
- C. TF Dissemination and time scales
- 2. Leap seconds in UTC and building a consensus for a continuous timescale
- 3. Promoting the mutual benefit of UTC and GNSS, subgroup on Traceability to UTC from GNSS measurement
- 4. Sharing Resources to Improve the International Timekeeping

(M. Gertsvolf, NRC; G. Mileti, Uni Neuchatel) (S. Bize, SYRTE; E. Peik, PTB; C. Oates, NIST) (D Calonico, INRIM; T. Ido NICT)

(J. Levine, NIST; P. Tavella, BIPM) (P. Defraigne, ORB; A. Bauch, PTB) (M. Gertsvolf NRC, Y. Hanado, NICT)

CCTF work in progress:

- CCTF Session 1 in October 2020: introduction of the topics, main issues, opening of a questionnaire to NMIs, UTC labs, Liaisons, Stakeholders (4 sets of questions)
- From Nov 2020 to Feb 2021, online questionnaire with > 200 answers
- CCTF session 2 in March 2021 to discuss main expectations/constraints/possible schedule and way forward
- October 2021: CCTF contribution to CGPM in 2022 with 2 draft resolutions
 - Draft Resolution D On the use and future development of UTC (+ accompanying document)
 - Draft Resolution E On the future re-definition of the second (+ accompanying document + Roadmap towards the redefinition of the SI second)
- Beginning of 2022: white paper on each hot topic
- Summer 2022: paper submitted to Metrologia
- June 30 July 1, 2022 23rd CCTF Meeting

CCTF Questionnaire online with Survey Monkey (4 sets of questions)

Category	Number of answers	
CCTF Members, Observers, and UTC contributors	78 (among which 24 CCTF members, 53 UTC(k) representatives)	> 200 answers
NMIs not yet contributing to UTC	12	
CCTF liaisons	4	
Stakeholders	117	





Co chairs: N. Dimarcq and P. Tavella

3 subgroups

- A Request from user communities, NMIs, and Liaisons
- Chair : Marina Gertsvolf, Gaetano Mileti

B – Atomic frequency standards, and possible redefinition approaches

• Chair : Sebastien Bize, Ekkehart Peik, Chris Oates

C – TF Dissemination and time scales

• Chair : D Calonico, Tetsuya Ido

More than 40 people from all RMOs, from all CCTF members, from all CCTF WGs, working together to assess the possible roadmap for redefining the SI second

$\rightarrow Outputs:$

- Draft Resolution E On the future re-definition of the second + accompanying document
- Updated roadmap towards the redefinition of the SI second (with criteria and conditions)

Redefinition criteria / conditions

Achieved

n progress

Mandatory criteria **To be achieved** before changing the definition

Ancillary conditions corresponding to essential **Work still in progress** when the definition is changed - Validation that Optical Frequency Standards are at a level 100 times better than Cs (I.1, I.2)

---- And a tory achievements frontier

- Continuity with the definition based on Cs (I.3)
- Regular contributions of OFS to TAI as secondary representations of the second (I.4)
- Availability of sustainable techniques for OFS comparisons (II.1)
- Knowledge of the local geopotential with a sufficient uncertainty level (II.2)
- Definition allowing future more accurate realizations (III.1)
- Access to the realization of the new definition (III.2)
- High reliability of OFS (I.5)
- High reliability of ultra high stability T/F links (II.3)
- Continuous improvement of the realization and time scales after redefinition (III.3)
- Regular contributions of OFS to UTC(k) (I.6)
- Availability of commercial OFS (III.4)
- Improved quality of the dissemination towards users (III.5)

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Schedule options for the redefinition of the second

CGPM 2022:

- We have a validated roadmap
- We are able to propose a redefinition option

AND

 We have a clear, achievable and verifiable roadmap to satisfy mandatory criteria by 2025

CGPM 2026:

Redefinition

CGPM 2022:

We have a validated roadmap

BUT ♦

We still have more than one type of possible redefinition, with illustration of (dis)advantages for each type but we have a validated roadmap to reach consensus on which definition type, which radiation(s) by 2025

OR

The work to fulfill mandatory criteria is unlikely achievable by 2025

CGPM 2026:

- We are able to propose a redefinition option
 AND
- We have a clear, achievable and verifiable roadmap to satisfy mandatory criteria by 2029

CGPM 2030:

Redefinition

CGPM 2022:

- We have a validated roadmap BUT
 - We still have more than one type of possible redefinition, with illustration of (dis)advantages for each type
- OR •

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The work to fulfill mandatory criteria is long

CGPM 2026:

 We still have more than one type of possible redefinition but we have a validated roadmap to reach consensus by 2025

OR

• The work to fulfill mandatory criteria is unlikely achievable by 2029

CGPM 2030:

- We are able to propose a redefinition option AND
- We have a clear, achievable and verifiable roadmap to satisfy mandatory criteria by 2033

CGPM 2034:

Redefinition

Fulfilment level of mandatory criteria (to be updated annually)



Mandatory criteria

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Fulfilment level of mandatory criteria (to be updated annually)



Mandatory criteria

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Contribution from Primary and Secondary Frequency Standards



Monthly updated plot https://webtai.bipm.org/database/show_psfs.html

Option 1: New definition based on a <u>single atomic reference transition</u> in the optical frequency range. Secondary representations of the second are provided by frequency standards based on other species. Caesium becomes a secondary representation of the SI second.

Option 2: New definition based on an <u>ensemble of reference optical frequencies</u>

Use of the weighted geometric mean of an ensemble of chosen transition frequencies; the weight of each transition is initially fixed and inversely proportional to the squared uncertainty of best standards based on this transition at the time of the definition.

Each transition of the defined ensemble is a representation of the definition, including current Cs reference transition if it is part of the ensemble. \rightarrow Merging of the concept and use of primary and secondary representation of the second.

The list of chosen transitions and their weights are periodically updated, including transitions already part of the ensemble or not yet part of it, and taking into account the evolution of the uncertainty of the best standards based on the chosen transitions.

Option 3: New definition based on <u>fixing the value of another fundamental constant</u>, as it has been done for other SI units. The Mise en Pratique would be based on atomic transition(s), either one as in Option 1 or an ensemble as in Option 2.

 \rightarrow Today, Option 3 not achievable as there is not a fundamental physical constant known with the necessary accuracy.

Updated roadmap towards the redefinition of the SI second (+ white paper)

<u>Resolution (Resolution E) proposed for CGPM</u> On the future re-definition of the second , concerning the goal of achieving a better definition and realization of the SI second possibly by 2030, and not later than 2034, in order to serve current and future needs in metrology and to foster scientific and technological application at the highest accuracy.

<u>Actions for the community:</u> (i) Pursue efforts to develop, operate and compare optical frequency standards providing regularly contributions to TAI with secondary realizations of the second. (ii) Support the promotion and investment in the research activities, the development of national and international infrastructure, and collaborative projects

Actions for CCTF:

Poids et

Finalization of the white paper in 2022, including the methodology for the future choice of the new definition Validation of the updated CCTF strategy at 2022 meeting

Possible actions for CCU:

Analysis of a possible impact of the new definition on the other unit definitions Reflection on the innovative approach of Option 2 for the redefinition ("Dynamic definition")





Thank you for your attention

