Report from the CCTF
Status of the planned redefinition of the second
Noel Dimarcq, Patrizia Tavella
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  
     (M. Gertsvolf, NRC; G. Mileti, Uni Neuchatel)
   - **B.** Atomic frequency standards, and possible redefinition approaches  
     (S. Bize, SYRTE; E. Peik, PTB; C. Oates, NIST)
   - **C.** TF Dissemination and time scales  
     (D Calonico, INRIM; T. Ido NICT)

2. **Leap seconds in UTC and building a consensus for a continuous timescale**  
   (J. Levine, NIST; P. Tavella, BIPM)

3. **Promoting the mutual benefit of UTC and GNSS, subgroup on Traceability to UTC from GNSS measurement**  
   (P. Defraigne, ORB; A. Bauch, PTB)

4. **Sharing Resources to Improve the International Timekeeping**  
   (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)

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of answers</th>
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<tbody>
<tr>
<td>CCTF Members, Observers, and UTC contributors</td>
<td>78 (among which 24 CCTF members, 53 UTC(k) representatives)</td>
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<tr>
<td>NMIs not yet contributing to UTC</td>
<td>12</td>
</tr>
<tr>
<td>CCTF liaisons</td>
<td>4</td>
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<tr>
<td>Stakeholders</td>
<td>117</td>
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Task force on the roadmap for the redefinition of the SI second

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

→ 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

Validation that Optical Frequency Standards are at a level 100 times better than Cs (I.1, I.2)
- 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)

Mandatory criteria
To be achieved before changing the definition

Ancillary conditions corresponding to essential Work still in progress when the definition is changed

Mandatory achievements frontier
<table>
<thead>
<tr>
<th>Year</th>
<th>Options</th>
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| **CGPM 2022:** | We have a validated roadmap  
AND | 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 | Redefinition | Redefinition | Redefinition | Redefinition | Redefinition | Redefinition | Redefinition | Redefinition |

**CGPM 2022:**
- We have a validated roadmap
- We are able to propose a redefinition option
- We have a clear, achievable and verifiable roadmap to satisfy mandatory criteria by 2025

**CGPM 2026:**
- Redefinition

**CGPM 2026:**
- 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
- The work to fulfill mandatory criteria is unlikely achievable by 2025

**CGPM 2026:**
- We still have more than one type of possible redefinition but we have a validated roadmap to reach consensus by 2025
- The work to fulfill mandatory criteria is unlikely achievable by 2029

**CGPM 2030:**
- We are able to propose a redefinition option
- We have a clear, achievable and verifiable roadmap to satisfy mandatory criteria by 2029

**CGPM 2034:**
- Redefinition
Fulfilment level of mandatory criteria (to be updated annually)

Mandatory criteria

- I.1 - OFS accuracy budgets
  - 2021

- I.2 - Validation of OFS accuracy budgets
  - 2021

- I.3 - Continuity with the definition based on Cs
  - 2021

- I.4 - Regular contributions of OFS to TAI
  - 2021

- II.1 - Availability of sustainable techniques for OFS comparisons
  - 2021

- II.2 - Knowledge of the local geopotential
  - 2021

- III.1 - Definition allowing future more accurate realizations
  - 2021

- III.2 – Access to the realization of the new definition
  - 2021

Achievement level

- < 30%
- 30-50%
- 50-70%
- 70-90%
- 90-110%
- > 110%

To be confirmed, based on the chosen redefinition option
Fulfilment level of mandatory criteria (to be updated annually)

Mandatory criteria

I.1 - OFS accuracy budgets
   2021

I.2 - Validation of OFS accuracy budgets
   2021

I.3 - Continuity with the definition based on Cs
   2021

I.4 - Regular contributions of OFS to TAI
   2021

II.1 - Availability of sustainable techniques for OFS comparisons
   2021

II.2 - Knowledge of the local geopotential
   2021

III.1 - Definition allowing future more accurate realizations
   2021

III.2 – Access to the realization of the new definition
   2021

Achievement level:
- < 30%
- 30-50%
- 50-70%
- 70-90%
- 90-110%
- > 110%
Contribution from Primary and Secondary Frequency Standards

Monthly updated plot https://webtai.bipm.org/database/show_psfs.html
Options envisaged for the new definition

**Option 1**: New definition based on a single atomic reference transition 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 ensemble of reference optical frequencies
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. → 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 fixing the value of another fundamental constant, 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.
→ Today, Option 3 not achievable as there is not a fundamental physical constant known with the necessary accuracy.
Conclusions

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

Resolution (Resolution E) proposed for CGPM 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.

Actions for the community: (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:
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