

The roadmap to the redefinition of the SI second

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on behalf of the CCTF task force on the redefinition of the second [1]

In the last 10 years Optical Frequency Standards (OFS) has shown a consolidated capacity to ensure a relative accuracy at the level of 10^{-18} , one hundred times better than the current frequency standard realizations based on the cesium atom. The debate on a possible redefinition of the second is very much alive.

The Consultative Committee for Time and Frequency (CCTF) established a Task Force [1] in 2020 to update the roadmap towards the redefinition of the SI second, following a first roadmap agreed in 2016. This paper illustrates the work of the entire task force [2] formed by about 40 people representing the CCTF countries, with some additional experts.

The Task Force was organized with three subgroups:

- A. Requests from user communities, National Metrology Institutes and Liaisons
- B. Atomic frequency standards, and possible redefinition approaches
- C. Time and Frequency dissemination and time scales.

that gathered feedback on the redefinition of the second through a global consultation of concerned communities and stakeholders through an online survey from December 2020 to January 2021. The needs and possible impacts of a new definition was evaluated, not just scientific and technological, but also regulatory and legislative.

The debate is largely dedicated to the choice of the new definition which could be based on three options:

1. choosing another atomic transition to replace the Cs hyperfine transition,
2. creating an ensemble definition by the weighted geometrical mean of the frequencies of an ensemble of chosen transitions,
3. fixing the numerical value of one more fundamental constant, in addition to c , h and e , as for example the electron mass or the Rydberg frequency.

The CCTF has updated mandatory criteria and conditions that quantify the status of the developments and their maturity for a redefinition. The main achievements and the open challenges related to the status of the optical frequency standards, their contribution to time scales and UTC, the possibility of their comparison and the knowledge of the Earth's gravitational potential at the necessary level of uncertainty are considered (fig 1).

The fulfillment level of those mandatory criteria is annually evaluated by the CCTF. At the last General Conference on Weights and Measures (CGPM) in Nov 2022, the fulfillment level was presented (fig 2) and a resolution has been adopted [3] aiming to encourage the NMIs and research laboratories to pursue the goal of the roadmap and bring proposals to the CGPM (2026) about the further steps that must be taken for a new definition to be adopted by the CGPM (2030).

	Mandatory criteria	Ancillary conditions	Criteria and conditions
Frequency standards, including the contribution of OFS to time scales	X X X X	X X	I.1 - Accuracy budgets of optical frequency standards I.2 - Validation of Optical Frequency Standard accuracy budgets – Frequency ratios I.3 - Continuity with the definition based on Cs I.4 - Regular contributions of optical frequency standards to TAI (as secondary representations of the second) I.5 - High reliability of OFS I.6 - Regular contributions of optical frequency standards to UTC(k)
TF links for comparison or dissemination	X X	X	II.1 – Availability of sustainable techniques for Optical Frequency Standards comparisons II.2 – Knowledge of the local geopotential with an adequate uncertainty level II.3 – High reliability of ultra-high stability TF links
Acceptability of the new definition	X X	X X X	III.1 - Definition allowing more accurate realizations in the future III.2 – Access to the realization of the new definition III.3 - Continuous improvement of the realization and of time scales after redefinition III.4 - Availability of commercial optical frequency standards III.5 - Improved quality of the dissemination towards users

Fig 1: Mandatory criteria and ancillary conditions to ensure the benefit and the acceptability of a new definition.

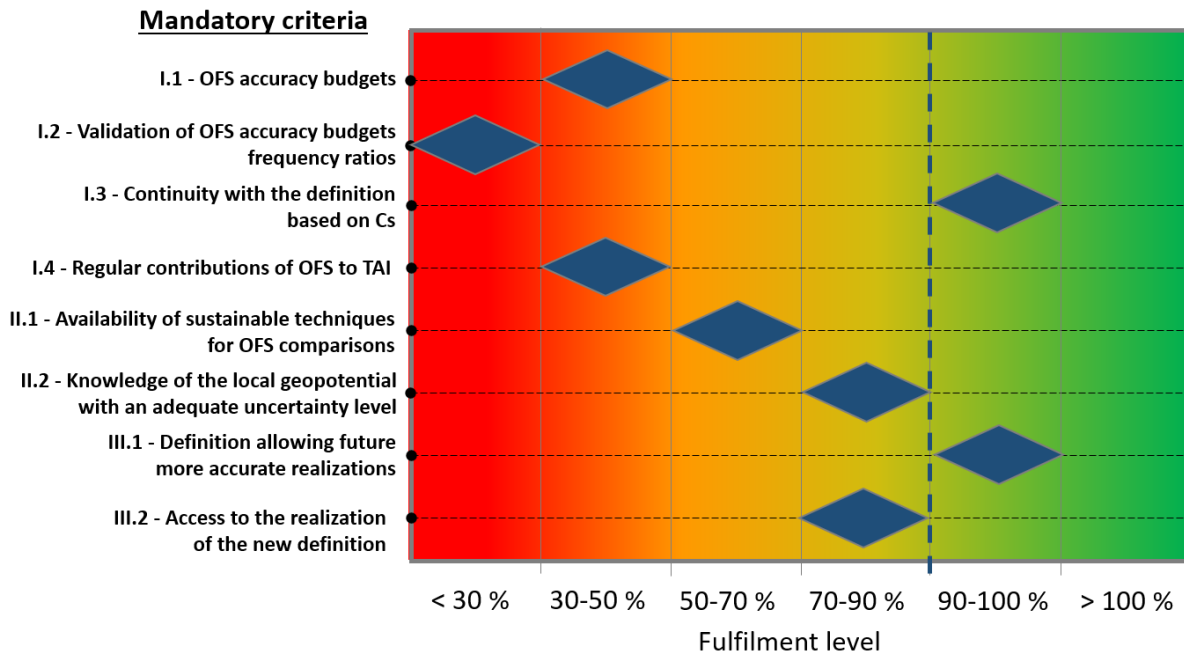


Figure 2: Fulfilment levels of mandatory criteria in 2022

References

- [1] CCTF Task Force on Updating the Roadmap for the redefinition of second, <https://www.bipm.org/en/committees/cc/cctf/wg/cctf-tfu>
- [2] N. Dimarcq et al, “Roadmap towards the redefinition of the second, submitted to Metrologia, <http://arxiv.org/abs/2307.14141>
- [3] Resolution 5 of the 27th CGPM (2022), “On the future redefinition of the second”, <https://www.bipm.org/en/cgpm-2022/resolution-5>