CCTF

Task Force on the Roadmap for the redefinition of second

Subgroup C: Time and frequency dissemination and time scales

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FOR TIME AND FREQUENCY

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External Experts:

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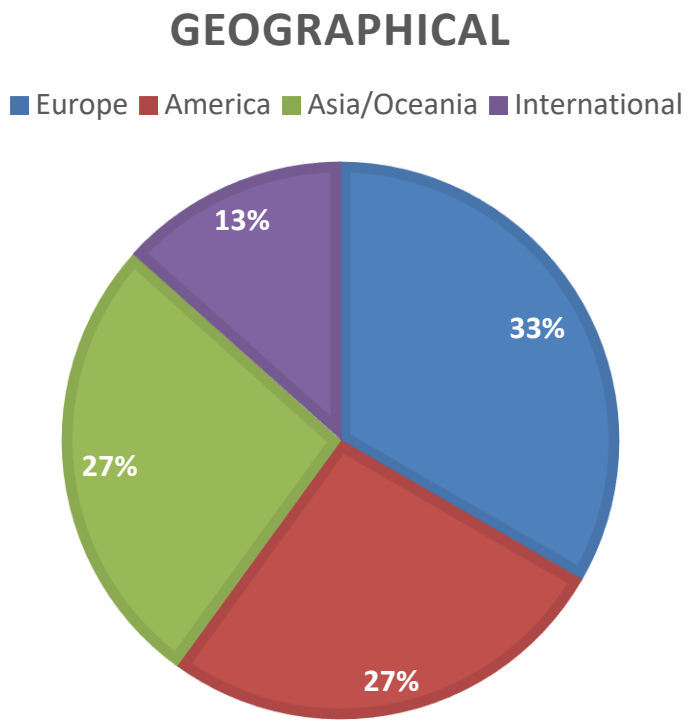
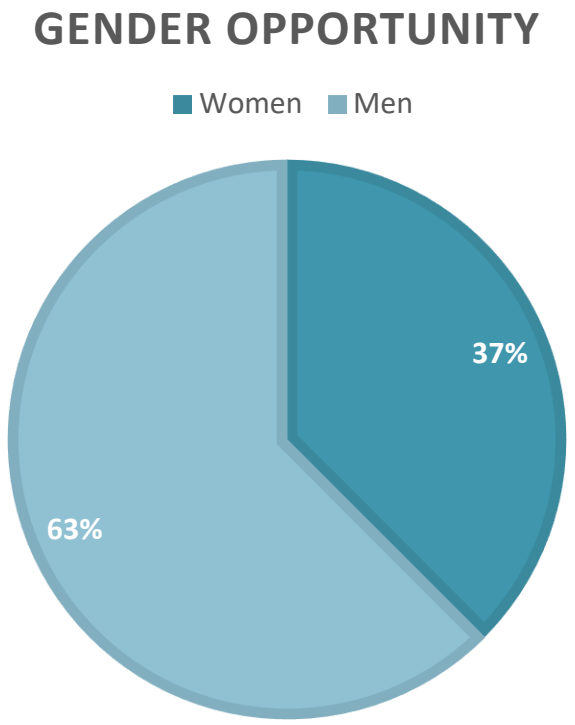
Membership

Membership/inclusivity





Aims

- To prepare a detailed roadmap of the redefinition of the second for the CGPM 2022 identifying the intermediate objectives and open issues, based on information gathering and critical assessment.

- **Fundamental Questions to be answered:**

1. What are the criteria for the redefinition? the current road map and other possibilities?
   a. class of criteria: scientific, organisational, universal acceptability
   b. are NMIs ready?
2. What is our **capacity to compare and disseminate** a realization of the second at 10^{-18} ?
   a. Status and envisaged evolution of T/F transfer techniques
   b. What are the **limits in computing the gravity potential** at 10^{-18}
3. What is our **capacity to include optical standards in the realization of a time scale**?
   a. Role of “optical” and “microwave” PSFS in UTC(k) and UTC
4. Which other **open questions** that require an answer to decide on the redefinition?

Focus Points

A. Capacity to compare and disseminate optical standards at 1e-18

B. Capacity to compute the gravity potential at 1e-18

C. Capacity to include optical standards in the realization of a time scale

Compare and disseminate optical standards at 1e-18

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Compare and disseminate optical standards at 1e-18

- WG-GNSS, WG-TWSTFT, and WG-ATFT represented in TF-subC
- Survey of activities relevant to optical standards comparisons and dissemination
- State of the art and publications

Discussion shall address

- The techniques that the community relies upon for T/F primary metrology
- The techniques available for achieving 1e-18 uncertainty in the frequency links
- The techniques not yet fully demonstrated in T/F but potentially useful
- Institutions and groups that work/plan to work on these topics
- What the community needs routinely, what is needed in special cases

Challenges /1

- Presently, only fibre links seem to be suited for remote comparisons at 1e-18 level
- Presently, only satellite techniques offer intercontinental comparisons, but not at the target uncertainty level
- Unavailability of T/F links with uncertainties < 5×10^{-18} in frequency at national / continental / worldwide scale to compare optical clocks
- Robustness and performances of transportable optical frequency standards
- Other techniques that are potentially useful: free space optical transfer, TW-CP, VLBI techniques….
- Need for wider campaigns of comparison of optical clocks in different institutes at few parts in 1e18 level either by transportable clocks, advanced links, or frequency ratio closures.
- T/F link robustness: high technology readiness level and continuous operation capability
- Capability of repeated uncertainty estimations and calibrations for T/F links

Compute the gravity potential at 1e-18

Compute the gravity potential at 1e-18

- International Association of Geodesy represented - Novel Sensors and Quantum Technology for Geodesy (QuGE, chair Prof. Müller, http://quge.iag-aig.org), WG Q.3: Relativistic geodesy with clocks
- WG Q.3 identifies an important interaction between geodesy and optical clocks to assess the consistency of height networks, to define a height reference and to ensure its long term stability.
- Survey of activities relevant to optical standards and geodesy
- State of the Art and publications

Discussion shall address

- Given the present reference, consider the gravity potential uncertainty and the possibilities for improvements
- Whether the present evaluation of the redshift at a given location is adequate for the redefinition
- Consider how to address the time-varying components of the gravity potential
- Institutions and groups that work/plan to work on these topics

Challenges /2

- Definition and Realization of the SI second and the appropriate reference for gravity corrections.
- How, and how well, we can compute the gravity potential, thus the relativistic frequency shift, at the locations of the clocks (aiming at 1e-18). Identify conventional methods to perform this computation, interacting with geodesy experts on the gravity potential.
- Establishing the validity of chronometric levelling at 1e-18; required progress in clocks and comparison techniques.
- Consider time variations of the geopotential. Tidal variations should follow established geodetic conventions. Other (non-tidal) variations should be studied.
- Once we have the clocks and frequency transfer techniques characterized at 1e-18, how we can contribute to the global models of the gravitational potential and to the definition of a global height system.
- Enhance interactions between NMIs and geodesy groups developing regional gravity and geoid models.
- Contribution to geodesy / oceanography / geophysics by using our clocks as measuring devices.

Include optical standards in the realization of a time scale

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Include optical standards to realize a time scale

- WG-TAI and WG-ALGO represented in TF-subC
- Survey of activities relevant to optical standards and optical timescale
- State of the art and publications on these topics

Discussion shall address

- What is mandatory (concerning time scales) for the redefinition.
- What are the algorithms required to treat the data from optical frequency standards.
- Whether to create a hybrid time scale with HMs, or directly pure optical time scales using optical flywheels.
- Institutions and groups that work/plan to work on these topics.

Challenges /3

- General discussion on the definition of an optical time scale
- Continuous operation of OFS and methods to compare clocks. The goal is to transfer the information of the comb to H-masers or optical flywheels.
- Demonstrated high-performance optical flywheel: effective, solid implementation of an optical reliable flywheel in UTC(k), avoiding the H-Maser?
- How to improve and keep at least at the present level the distribution of optical and RF standards?
- From the point of view of algorithms for UTC(k), an important question is what is the best way to include not phase, but frequency data from a primary reference device that will probably not run continuously, requiring a treatment of the dead time.
- How to estimate the uncertainty of the frequency of optically steered UTC(k).
- TAI/UTC: How many and how regularly can optical clocks contribute?

Methodology

1. Monthly meeting with members (remote conferences) / BIPM sharepoint
2. Questionnaire for CCTF members - elaborations based on TF-C aims
3. Database with available literature
4. Existing Roadmaps from different bodies with respect to TF-C topics
5. Interaction with Group A and Group B
6. Interaction with other external experts
7. Reporting to Task Force Chairs (Reporting Document)

List of Questions to CCTF members

- Which techniques have you implemented/planned to implement for T/F comparisons?
- What are their performances ?
- Do you have/plan to have links capable of 1e-18 accuracy level?
- How do you calibrate/plan to calibrate your time links?
- Are you working/planning to work on innovative comparison techniques? Which ones?
- Are you working/plan to work on transportable optical standards?
- What are their performances ?
- Which are your plans for intercontinental comparisons?
- Are you planning to improve your contribution to TAI? How?
- Are there any plans to connect your NMI to other national institutions developing optical standards?
- Who are your national stakeholders for a better timescale that includes contributions from optical clocks?
- Are you collaborating with geodetic groups in your country?
- Are you working to improve the knowledge of red-shift correction at your site?

Thank you.

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