

## **Guidelines for reporting primary (PFS) or secondary (SFS) frequency standards data for TAI calibration**

The comparison of primary (PFS) or secondary (SFS) frequency standards with TAI is indispensable to ensure the accuracy of the TAI scale unit and its conformity with the SI second. The comparison is affected through an intermediate, a comparison to a clock contributing to International Atomic Time (TAI) via reports of UTC(k) – clock in the institute's TAI clock file, or comparison with UTC(k) directly. A list of secondary representations of the second that can so contribute is provided by the BIPM at <https://www.bipm.org/en/publications/mises-en-pratique/standard-frequencies>.

A precondition is that the CCTF Working Group on Primary and Secondary Frequency Standards (WG PSFS) has reviewed and approved this standard. The first submission of a new standard should follow the guidelines in section 1.

After approval by the WG PSFS, subsequent submissions of measurements follow the guidelines in section 2.

The procedures covered by these guidelines derive from Recommendations CCTF 2 (2004), CCTF 3 (2006) and CCTF PSFS 3 (2020/21)

### **1. Guidelines for the first submission of a new PFS and SFS for TAI**

The first submission of a new PFS or SFS to the BIPM Time Department should include

- a peer-reviewed publication (published or at least accepted for publication) about the standard and its frequency uncertainty evaluation; additional publications may be provided as deemed useful;
- at least three (preferably five or more) first reports of frequency measurements, following the guidelines in section 2, evaluated over several months.

Based on the data in the submitted first reports, the staff of the BIPM Time Department will generate the first tentative TAI calibration data for the new PFS or SFS and will transmit all the material to the WG PSFS. The members of the working group will assess the submitted material and check whether the tentative calibration data is compatible with the results of other PFS and SFS utilized for the calibration of TAI in the same or in similar periods as covered by the submitted reports.

Having assessed all the data, together with the related reports and the publication(s) of the new standard, the members of the WG PSFS may request further information or ask for changes or amendments in the reports. After acceptance by the WG PSFS, the initially submitted data is included as formal TAI calibration data in retrospect. At that time, they will contribute with small weight, because of the delayed consideration.

The BIPM Time Department may similarly ask the advice of the WG PSFS in case of refurbishment or other very significant change in a previously approved PFS or SFS.

### **2. Guidelines for reporting PFS and SFS measurements for TAI**

Each PFS or SFS data intended for TAI steering needs to cover an evaluation interval multiple of 5 days, starting with a Modified Julian Date (MJD) ending with a "4" or a "9". The reporting interval of BIPM's Circular T ends on the last such date in the respective month, spanning 30 days in most cases, but occasionally also 25 or 35 days. It is recommended that the PFS evaluation interval is adapted to this period if this is not detrimental to the uncertainty of the measurement. However other multiples of 5 days are acceptable as well. Submission by the 4th of the following month is necessary for immediate inclusion in the TAI steering. In case the deadline cannot exactly be met, please contact the BIPM Time Department to agree on a possible delay.

For each PFS or SFS frequency measurement,

- the result of measurements should be reported in a file with a specific format, as described in the document [https://webtai.bipm.org/database/documents/psfs\\_format.pdf](https://webtai.bipm.org/database/documents/psfs_format.pdf).
- a report describing the operations should be sent to [tai@bipm.org](mailto:tai@bipm.org)

The last-mentioned report of operations has no specific imposed structure, but the following paragraphs provide some guidance on the content of the report.

The report should provide a comprehensive description of the prevailing measurement campaign, with information about the measurement period, the result, its uncertainty and the percentage of uptime of the standard. For all procedures involved in the determination of the result or its uncertainty, it is requested that any change compared to previous practice is explicitly described in the report. Moreover, such changes should be persistently described in each of the subsequent reports, at least until there is the possibility simply to cite an easily accessible publication, where the change is described.

In more detail, it should be considered that

- the frequency measurement (intermediate local reference – PSFS), where the reference may be UTC( $k$ ) or a clock participating to TAI, should be provided as one value at the middle of the evaluation interval. In order to provide at best the cancellation of the reference in later computing the frequency (TAI-PSFS), the reported frequency should be determined consistently with its use in the TAI algorithm, i.e. Frequency = (phase end – phase begin) / duration. To cope with different experimental realizations and the presence of deadtime in the operations of the PFS / SRS, it is recommended to use a linear fit to a set of individual frequency data to determine the reported frequency. However, the possible effect of a dissymmetry of the data points in the interval must be accounted for.
- the intermediate reference of the frequency measurement (be it a UTC( $k$ ) or a clock participating to TAI) should be in stable conditions during the PSFS evaluation. Intentional time or frequency adjustments to the intermediate reference during the report interval should be avoided and the correct behavior of the reference, as well as the correct report of the measures in the BIPM clock file should be checked. In case adjustments cannot be avoided, they must be mentioned in the PSFS report and consistently reported in the institute's clock data file.
- the uncertainty specification should include the detailed PSFS uncertainty budget at the period of the measurement and furthermore detail the following uncertainty contributions:
  - the statistical uncertainty  $u_A$  originating from the frequency instability of the measurement,
  - the combined uncertainty from systematic effects  $u_B$ , which includes the uncertainty of the gravity shift,
  - the uncertainties  $u_{A/lab}$  and  $u_{B/lab}$  in the link between the standard and UTC( $k$ ), from statistical fluctuations (including the uncertainty due to measurement dead-times DTU) for  $u_{A/lab}$ , and from systematic effects for  $u_{B/lab}$ . Even if the reference is a clock contributing to TAI, all relevant uncertainties up to UTC( $k$ ) should be included because the link between the laboratory and TAI is established through UTC( $k$ ).
- the percentage of uptime should indicate the true measurement period of (reference – PSFS) with respect to the total evaluation interval, i.e. dead time includes time intervals with outages or used for maintenance, parameter measurements and so on. Unless the DTU is insignificant with respect to the other sources of uncertainty, the report should include information such as the epoch distribution of dead times and the detailed components of the DTU.

All past reports (not necessarily following the present guidelines) may be found at <https://www.bipm.org/en/time-ftp/data> under “Reports of Evaluation of Primary and Secondary Frequency Standards”.