

# Practical implementation of a definition of the second based on several transitions

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A new definition of the SI second based on optical transitions is expected to be adopted within the next 10 years. Several options for this redefinition are currently under consideration. Among them, a definition based on several transitions<sup>1</sup> would take advantage of the variety of high performance optical frequency standards. This definition, labeled "option 2", is a generalization of a definition based on a single atomic species (or "option 1"). In this paper, we review practical aspects such a definition entails, and propose a detailed analysis of its strengths and weaknesses. In particular:

- We discuss the practical choice of the numerical constants defining the unit (normalization constant and weights), and illustrate it with several examples. We show that this choice unequivocally define the unit, independently of further improvement in frequency ratio measurements.
- We detail how the unit is realized in practice, with a focus on the behavior of the realization uncertainty when several clocks are jointly operated, e.g. when providing calibrations of TAI.
- We propose an in-depth explanation of why the unit is defined using a weighted geometric average, as opposed to an arithmetic average.
- We present the specific advantages of "option 2" : this option would facilitate the choice of species entering the definition, hence allowing for a faster consensus ; it is readily implementable with the current tools and methods in use in the time and frequency metrology ; it fosters the development of various frequency standards, and encourages the measurement of new or refined frequency ratios.
- We propose an analysis showing how to mitigate the drawbacks of options 2, especially concerning the added realization uncertainty, and how to relate the abstract definition to physical concepts, both for scientific and popular audiences.

Finally, we propose a compared analysis of option 1 and option 2 after the redefinition, in the case of a continued improvement of optical frequency standards, and discuss the advantages and drawbacks of a dynamic update of the defining values of the unit.

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<sup>1</sup> J. Lodewyck, "On a definition of the SI second with a set of optical clock transitions", *Metrologia* **56** 055009, 2019