Recommendation Concerning the Alternate Realizations of the Second

The rapid improvements in the realization of the second associated with the development and application of laser-cooling methods now raises the question of whether or not the cesium-133 atom provides the best possible basis for the definition of the second. Indeed, the fountain standards pioneered by the Laboratoire Primaire du Temps et Frequences (LPTF) have pushed the accuracy of cesium frequency standards to the point where it now seems that the abnormally large collision shift in cesium may limit the accuracy of these standards at (or somewhat below) their present levels.

Coupled with this, we have seen significant studies showing that microwave and optical standards based on other atoms and ions might prove to be superior to the cesium standard. We are thus entering an era in which it will be appropriate to test these new standards against cesium, in order to determine how well each of them might serve as a possible new definition for the second. This effort can be pursued in the present rather open situation, but the CCTF could also consider developing a structure in which standards developed through such studies can contribute to TAI, while their relative merits are studied.

The attached recommendation, which is based on informal comments that were made by several people at the last meeting of the CCTF, is offered as a means for systematically approaching the question of alternate standards. It is patterned on the CCL use of a *mise en pratique* for realizations of the meter. In fact this CCL document is really a list of optical frequencies that have been measured directly relative to the cesium frequency standard, so this proposal can be seen as only extending this general concept to other (secondary) realizations of the second.

This recommendation does not involve replacement of the current definition of the second. In fact, the studies that would follow its acceptance might lead to the conclusion that the current definition is a good one, and that it be retained. Thus, we might view this as a means for stimulating the study of standards based on other atoms and ions, and for subjecting these studies to review by the international community in a way that expands discussion of new possibilities.

While we understand that such alternate realizations of the second cannot be any more accurate than that based on cesium, a formal structure of this type will allow any given NMI to develop a new standard that can also contribute at some level to TAI. This would establish a dual purpose for the development (both research on and operation of the standard), and encourage laboratories to invest in new standards, since these could serve as real standards. TAI would also benefit by having more inputs from more standards.

We should finally note that research in this area has already progressed to the point where thefrequencies of transitions in promising atoms and ions have been measured relative to the cesium standard with exceptionally low uncertainty. It is likely that these and other measurements would be ready for presentation at the next meeting of the CCTF.

Recommendation Concerning the Realization of the Second

The Consultative Committee on Time and Frequency,

considering

--- that there are a number of new atoms and ions being studied as the potential bases for improved atomic frequency standards,

--- that new optical-frequency measurement concepts may allow use of optical transitions as practical frequency standards, since they provide for a direct microwave output from such standards,

--- that an important limiting effect in the realization of the second is the spin-exchange frequency shift,

--- that the spin-exchange frequency shift in cesium is much larger than it is in most other atoms,

--- that the *mise en pratique* used for realizations of the meter defines a set of high-accuracy optical frequency standards that are referenced to the cesium definition of the second,

recommends

--- that a *mise en pratique* for frequency standards be established to support alternate realizations of the second, with the provision that the fundamental definition based on the cesium-133 atom be left unchanged for now,

--- that, at its regular meetings, the CCTF considers accepting accurate frequency measurements of atom and ion transition frequencies made relative to the cesium frequency standard as alternative (secondary) realizations of the second,

--- that consideration be given to combining the set of frequency references used by the CCL and that used by the CCTF, thus providing the basis for realizations of both the second and the meter.