DISCUSSION CONCLUDING AAS 13-510

HARLAN STENN said that the United States is presently facing a "fiscal cliff that is so horrible that no one would ever allow it to happen, and the subsequent sequestration." Considering a comment from Nelson *et al*. (2001)[1] that a leap minute would be "relatively easy to adopt," STENN wondered how "anybody would expect that by pushing something off thirty, forty, or fifty years into the future, we would have this [leap-minute] thing nailed down well enough in twenty or thirty" years. If that was the case, then there should be every expectation that existing devices would already be able to track leap seconds. ROB SEAMAN interjected that he had intended to make "exactly the same point."

Continuing, STENN said he had seen many claims that leap seconds do not matter to very many people, and that is why we should get rid of them. Conversely, STENN has not seen much discussion as to why leap seconds matter to the people who care about them. SEAMAN replied that was essentially the subject of the previous colloquium in Exton. JOHN SEAGO elaborated by saying the Exton proceedings recorded some excellent discussions about why people cared about leap seconds. STEVE ALLEN added that similar kinds of discussions should be expected to come up during in this meeting. STENN clarified that it was not a question that he was asking personally; rather, he had seen the argument made too many times that "lots of people do not care so let's just get rid of them." To STENN, this argument seemed like "misdirection", to put it politely.

KEVIN BIRTH asked if there had been any consideration as to what time of day a leap minute would be inserted, because if it is inserted at the traditional time of midnight on the prime meridian, this would be the height of rush hour for the majority of Earth's population. Given the nature of public transportation systems, any idea that nobody would notice or care would strike BIRTH as strange. SEAGO regretted that he could not cover all aspects of the subject in his paper or in the allotted presentation time. He noted that his paper mentioned the time-of-day aspect, but it did not explore it very far, as there seemed to be no fair criterion that might be used to pose a time-of-day different from the end of the UTC day. Rather, SEAGO felt that there was a somewhat implicit assumption by leap-minute advocates that it should be applied just like a leap second is applied now. BIRTH said that it would seem that such advocates "would not care if they missed their train at the station; it really comes down to the fact that public transportation systems will handle this clumsily and this is being done in a part of the world which has the most of the world's population." Thus, disruption is maximized by choosing to implement a leap minute at midnight on the prime meridian. SEAGO speculated that a leap-minute occurrence on New Year's Eve, or over a weekend, might help to minimize some disruptive impacts.

ARNOLD ROTS said this was a discussion—in terms of our current world environment—about something that is supposed to be happening 35 years from now. A minute makes a noticeable difference in public-transportation systems today, but 75 years ago no one would have worried. Thus, extrapolating current experience 35 years into the future seemed unrealistic. If a switch to leap minutes was made now, it would alter the UTC system roughly 45 years after the introduction of leap seconds. And by the time the first leap minute became effective, most likely another

cycle of changes to timekeeping systems will have happened. So it seems unnecessary to contemplate that far ahead if indeed a leap-minute approach is adopted.

ANDREW MAIN raised a point about the notation for a leap minute. It makes perfect sense to represent the leap minute as 23:60 in UTC, and that representation would also apply to other time zones, where one would have 18:60 in New York, for example. But that representation only works for time zones that are integral-hours offset from UT, which not all time zones presently are. Leap seconds work because all current times zones are offset by integral minutes from UT (and in fact all time zones seem to be on multiples of quarter-hours). But there is no authority that can dictate that everyone must go to offsets of integral hours from UT to make leap-minute representation work. SEAGO acknowledged that this was an excellent point undeveloped in his paper.

SEAMAN kidded that certainly we should adopt leap minutes just for the entertainment value "just to yank our grandchildren's chains," which aroused laughter. SEAMAN then supposed that the implementation of the leap minute does not have to happen over one minute. There was a talk at the Exton colloquium about the 10,000 year clock; if that clock gets behind, its solar synchronizer corrects by one tick.[2] Thus, a leap minute might be implemented as one leap second per year for sixty years, and there are other entertaining options that could be explored.

In contrast to a point made about the leap minute being "easier on the quadratic problem," SEAMAN thought that the leap minute did not help this problem at all. It does not matter if adjustments are made one at a time or one thousand at a time; it is the same quadratic dilemma that will ultimately lead to redefining the second if humanity wants to keep its Babylonian system of timekeeping. SEAGO felt that Planesas' point was that the current UTC standard only allowed the insertion of up to twelve seconds per year, whereas a leap minute allowed sixty at once. But this is not really an issue, because it would be many centuries before the current standard no longer worked. SEAMAN remarked that, for those who do not read the leap-second mailing list,[*] the suggestion of the 'leap hour' was about the only thing on which everyone could agree: everyone thought it was "the dumbest idea".

CHRIS TUASON asked if SEAGO's paper advocated a particular approach to implementing a leap minute, such as two half-minutes, *etc*. SEAGO replied that no particular implementation approach was strongly advocated; however, SEAGO felt that alternative approach such as two half-minutes might not be deemed as a "leap minute". In fact, he cautioned that his research did not actually "advocate" the leap minute as much as it advocated its exploration and discussion. This is because people continue to suggest the leap minute as a potential compromise, yet few implementation details have been proposed outside of Planesas' IERS questionnaire response. SEAMAN found interesting SEAGO's list of how many times the leap minute had come up, but "of course the comment[†] from Judah Levine [of NIST] is exactly right; it does no good for astronomers. We would have to change all our software no matter what, if they did that."

DANIEL GAMBIS said the question is whether we want to replace the current system of rollbacks using leap seconds with much larger rollbacks. SEAGO agreed that is the fundamental question. SEAGO replied that he was not convinced that larger steps satisfied current operational requirements, simply because system-testing benefits most from more frequent adjustments, not less.

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[*] http://six.pairlist.net/mailman/listinfo/leapsecs
[†] "A minute is an intolerably long period of time."

STEVE MALYS offered an observation along the same lines as SEAMAN's last point: a leap minute would require a lot of satellite and astronomical software modifications to permit UTC to diverge from UT1 by more than one second, and this would be a significant disadvantage. SEAMAN felt that one should assume that the intent of proposing a leap minute is to never allow it to happen. SEAGO agreed, saying that once a decision is made to change over to leap minutes, timekeeping technology is essentially decoupled from Earth rotation. There would be little incentive to actually implement the leap minute once the scheduled time comes, because the pain of that cure might seem "worse than the disease" of divergence from Earth rotation.

Personally, YASUHIRO KOYAMA was partial to supporting the idea of leap minutes. However, he was unsure why the introduction of a leap minute should be limited to being introduced when |UT1−UTC| was a few seconds from sixty. SEAGO clarified that was a specific element of Planesas' proposal recorded in the IERS questionnaire results, but SEAGO did not know the motivation of that particular criterion. KOYAMA thought that a window of ±60 seconds for |UT1−UTC| would provide greater flexibility. SEAGO rhetorically asked who might be willing to propose a window of opportunity as large as ±60 seconds so as to allow the *early* introduction of a leap minute, say, in 2020. SEAGO thought that introducing a leap minute sooner rather than later would be the fairer approach, yet he wondered how people would react if they had to *really* implement a leap minute in, say, five or ten years. STEVE ALLEN then reminded the attendees that the Google "leap smear" was motivated by the fact that "a company with the resources of Google could not undertake the analysis of the implications in the software for *one second*. The leap minute would figure into a scenario which the ITU-R fears—that everyone simply disregards the recommendation."

REFERENCES

[1] Nelson, R.A., D.D. McCarthy, S. Malys, J. Levine, B. Guinot, H.F. Fliegel, R.L. Beard, T.R. Bartholomew (2001), "The leap second: its history and possible future." *Metrologia*, Vol. 38, p. 524.

[2] Hillis, D., R. Seaman, S. Allen, J. Giorgini (2011), "Time in the 10,000-Year Clock." Paper AAS 11-665 from *Decoupling Civil Timekeeping from Earth Rotation—A Colloquium Exploring Implications of Redefining UTC*. American Astronautical Society Science and Technology Series, Vol. 113, Univelt, Inc., San Diego. pp. 79-93.