DISCUSSION CONCLUDING AAS 13-522

CHRIS TUASON said "it was really a good thing" that the SI second was chosen to be too short relative to the mean solar second; the fact that leap seconds all step in one direction makes adjustments easier. RUSSELL REDMAN replied that it does not necessarily make adjustments easier, but rather the adjustment had never actually gone the other way. The fact that there was a seven-year period (1998 - 2005) with no leap second reveals just how close we are to an occasional negative leap second which has not happened. ANDREW MAIN said this was not by luck; it was because the length of the SI second is based on historical observations from the late 18th century to the end of the 19th century,[1] and there had been some secular slowing since then. DANIEL GAMBIS replied that, at the same time, the SI second was probably taken too short in view of the present situation where the mean solar day is now about 86400.001 s SI (so even if the Earth rotated uniformly, a leap second would still be needed from time to time). However, DENNIS MCCARTHY thought that the short duration of the SI second was because the observations behind Ephemeris Time were basically what Newcomb used.[2]

Regardless, GAMBIS agreed that the abbreviation of the SI second was fortunate, because if a leap second was removed instead of added, it would be "a nightmare" and result in "a lot of confusion." REDMAN agreed that if there is ever a negative leap second, then "a whole bunch more codes" will break than are already breaking now. MAIN said that was a good reason for proposals suggesting that we ought to leap as often as possible—both forward and backward—because that would exercise all of the code regularly, and this would result in far fewer problems in the long run. MAIN's comment fostered some nervous laughter and skepticism around the room. MCCARTHY thought that practice would find different problems and STEVE ALLEN thought this proposal reflected a want of operating-system people to either "leap all the time, or never."

JOHN SEAGO wondered if people sometimes forget about leap seconds scheduled into the future. He asked GAMBIS if the IERS had contemplated issuing *Bulletin C*[*] more frequently, say every month, especially if leap seconds are predicted much further in advance. GAMBIS thought it "could be useful" but hesitated to say for sure. MAIN thought this suggestion was conflating multiple ideas. There is the 'application horizon', and then there is the 'scheduling cadence' which had not yet been discussed. Currently, *Bulletin C* is issued for each June and December, but the ITU-R standard allows for a leap second at the end of every month. MAIN thought there ought to be an explicit statement as to when there will *not* be a leap second. Regarding a reminder of leap seconds that have been scheduled but have not yet occurred, MAIN thought it logical that such a reminder probably would be best left as a separate bulletin from the original scheduling decisions.

SEAGO clarified that he was thinking that the bulletin might declare the months when leap seconds do or do not occur as far in advance as leap seconds have been determined; this table could be updated as frequently as once per month. MARTIN BURNICKI thought that approach

[*] http://www.iers.org/IERS/EN/Publications/Bulletins/directLinks/bulletin__C__MD.html

seemed "a little bit heavy" as people would stop paying attention to bulletins emailed as frequently as once per month. BURNICKI thought that the semi-annual bulletins were sufficient: a user looks to see if there is a new leap second in six months and thereafter is okay. BURNICKI thought the problem was not the lack of frequency in bulletins, but the lack of frequency of actual leap seconds, between which there is sometimes long intervals. Based on BURNICKI's arguments, GAMBIS surmised that a monthly bulletin would perhaps provide "too much information." BURNICKI said he was sure of this: "if someone receives a newsletter from a company once per month or once per day, it will be ignored."

REDMAN did not want to appear too cynical, but he supposed if the bulletin is repeated too often, then people will either ignore it or they will make mistakes. ROB SEAMAN said that it seemed possible to continue the current reporting interval of six months, but according to GAMBIS's work the IERS could lengthen the prediction interval to something like three years at a 95% confidence level. SEAMAN wanted to know what it would take practically and politically to make that happen, such that the next *Bulletin C* predicts leap seconds for the next three years, with the prediction window sliding every six months thereafter. GAMBIS was not sure he understood SEAMAN's question about "prediction interval". SEAMAN clarified that UT1 predictions could be made, but those "predictions would need to be turned into decisions of whether there is a leap second or not" within the next three-year horizon. GAMBIS said that predicting out to three years might be risky; two years might be more appropriate.

JIM KIESSLING interceded, asking if there was an authority that GAMBIS would need to consult to change the format of *Bulletin C* to accommodate SEAMAN's proposal. GAMBIS assumed that it would be a decision of the IERS Directing Board; SEAMAN also added that he did not think the ITU-R restricted how far the IERS can predict. MCCARTHY said that it was possible to do; the ITU-R rules were "sort of written the other way around," where there was no limit on how far future leap seconds can be predicted, but the IERS "must report the occurrence or non-occurrence of a leap second six-months beforehand." MAIN believed the official ITU-R minimum was much smaller—around six weeks; SEAGO clarified that the rule was eight weeks. MCCARTHY said that, irrespective, the IERS had "made it an effective rule of six months." MCCARTHY figured that it would be very dangerous to predict too far ahead because a 95% confidence level does not preclude the possibility of a lot of bad things happening. GAMBIS agreed. SEAMAN proposed first doubling the current six-month horizon to a year to decide whether that works.

HARLAN STENN conjectured that "all it takes is one *really* good earthquake" to affect predictions of Earth rotation. This led KIESSLING to wonder about the overall impact on Earth rotation rate for an impulsive event such as the 2011 earthquake that caused the Fukushima tsunami. GAMBIS was not sure that event was visible in the Earth-rotation data. But even without such an event, KEVIN BIRTH speculated that predicting too far into the future might cause problems for people who just start proactively programming in multiple leap seconds that do not happen.

MAIN responded that the discussion seemed to be confusing the estimation of when leap seconds should happen with the decisions to insert them. MAIN noted that the current discussion was interested in the actual decisions; estimation as it was precisely discussed before was not useful to the present discussion regarding bulletin announcements. ALLEN echoed this point, saying that *Bulletin C* needs to be something "absolutely authoritative" by declaring if a leap second will or will not occur; ALLEN was not sure if the discussion was starting to hint at the development of a separate bulletin to suggest what *might* happen. Many in the room simultaneously bemoaned this suggestion. MCCARTHY uttered "that would be extremely dangerous," and MAIN agreed that "would be confusing."

BURNICKI said that from his company's experience, it does not matter anyway whether the leap second is announced six months before or two weeks before, because most users start testing just a few weeks before the leap second happens, and before that they do not care. GAMBIS therefore asked if BURNICKI was suggesting whether additional information be sent (two weeks before). BURNICKI clarified that "everything is good as it is" and there was no need to change current frequency of notifications. It was sufficient to give notice one-half year in advance; developers do not care and will just wait until a few weeks before to test if everything works. GAMBIS jested that perhaps some lightning could appear on the IERS web site as a precaution, which amused the audience.

ALLEN added that in many practical senses, IERS *Bulletin A*[*] already provides a means for anticipating leap-seconds: one can just look at the values and discern when a leap second might be needed. MAIN revealed that he had drawn such predictions from *Bulletin A* when talking at Perl conferences as a useful means of discussing just what kind of information is in *Bulletin A*.[†] TUASON asked in jest if the IERS had considered hiring some astrologers, which added more levity.

With regard to a histogram displayed by GAMBIS, SEAGO noticed that the criterion was indicated as being for one second, whereas the prescribed tolerance for (UT1−UTC) is ±0.9 seconds. SEAGO wondered whether the actual analysis was with ±0.9 s or ±1 second, and whether that should make any difference in the results. GAMBIS thought that the analysis was done with ±1 second as indicated, but he also supposed that it did not it matter much.[‡] SEAGO also said there was a noticeable change-point in the rotation rate of the Earth in 1998; he wondered about the performance of the predictions after that change-point specifically. GAMBIS said that the predictions would have been wrong actually, with the characterization beyond that point changing rapidly. When SEAGO thought that interval would have likely been part of the five percentile for which a multi-year horizon would not have worked, GAMBIS affirmed "Yes, yes."

REFERENCES

[1] Markowitz, W., R.G. Hall, L. Essen, J.V.L. Parry (1958), "Frequency of Cesium in Terms of Ephemeris Time." *Physical Review Letters*, Vol. 1, No. 3, pp. 105-07.

[2] Newcomb, S. (1895), *The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy*. Supplement to the American Ephemeris and Nautical Almanac for 1897. Government Printing Office, Washington.

[*] http://www.iers.org/IERS/EN/Publications/Bulletins/directLinks/bulletin__A__MD.html

[†] http://www.presentingperl.org/lpw2011/why-time-is-difficult/

[‡] *Editors' Note*: AAS 13-522 was amended following the discussion to reflect an analysis at ±0.9 s.