DISCUSSION CONCLUDING AAS 11-671

George Kaplan ended his presentation by noting that if leap seconds are removed from UTC, then the UT1 ≈ UTC assumption is no longer valid. This requires either re-labeling "UT" as "UT1" and educating users about the conversion from UTC to UT1, or changing "UT" tabulations to be explicitly based on UTC and using predicted values of UT1–UTC to compute the data. Steve Allen asked whether that choice would be made by evaluating user preferences or by deciding on behalf of users. Kaplan said that thinking had not progressed that far, but major almanac changes tended to elicit user input. Unfortunately, the users do not always provide sufficient feedback.

McCarthy speculated that by the year 2020 (after the possible retirement of the leap second), electronic versions of the almanac may largely replace printed almanacs. Kaplan said that situation exists already, noting that the *Nautical Almanac* is available in electronic form now, and internet web services get an enormous number of users. McCarthy said that the value of UT1-UTC could be updated very frequently in that situation; Kaplan agreed that it could be updated daily if the user preferred.

Neil deGrasse Tyson asked about the degree of differences in various national almanacs. Kaplan said that the data in various national almanacs are consistent to a very high degree (on the order of milliarcseconds, because they all originate from the same astronomical ephemerides), but that different national almanacs may choose to display different content depending on the expectations of their customer base. Steve Malys added that there are obvious language differences.

With regard to educating users about the differences between "UT" and "UTC", David Simpson shared an anecdote about an acquaintance who had heard about the proposal to redefine UTC, and believed that in 2018 we would not only stop adding future leap seconds from UTC but we would retroactively eliminate all past leap seconds from the definition of UTC as well. Kaplan said that it is worth pointing out that if future leap seconds were eliminated from UTC then we would have three (3) time scales approximately offset from each other by a constant amount: UTC, TAI, and TT. All are basically realized from the *SI* second on the geoid. Rots commented that one could add GNSS time scales to this list, such as GPS time.

McCarthy noted that there is a technical difference between TT and TAI that is more than a constant offset of 32.184 seconds. Kaplan concurred that the definition is different. McCarthy noted that plots of TAI-TT differences exist.[1] Seidelmann clarified that TT is a more ideal version of TAI, where TAI reflects how well the TAI second was realized.[2] McCarthy added that TAI had historically varied due to slight changes in its realization, such as blackbody corrections, *etc*. Kaplan noted that TT is now defined relative to Geocentric Coordinate Time (TCG), which almost seems backwards in terms of how it is practically realized today by most people. McCarthy conceded that most people find TCG from TT = TAI + 32.184 although these are defined in the opposite way.

John Seago noted that the options to change "UT" in almanacs to either "UTC" or "UT1" seemed like a rather subtle matter for a user base that may not have ever understood that there

was a distinction. Seago asked whether there might be some benefit to retiring the name "Coordinated Universal Time" and the acronym "UTC" and replacing it with something that would not be as easily confused with Universal Time. Kaplan replied that if UTC didn't exist, it might raise legal issues wherever national timescales refer to something called "UTC". McCarthy offered that a British colleague had proposed the name "Global Mean Time" to preserve the acronym "GMT".

Seaman pointed out that the more immediate discussion seemed "focused on the solution." In comparison, the discussion of the subtle differences between TT and TAI, was more of an "exploration of the problem space." Seaman's preference was that the discussions should sufficiently explore the problem space instead of tweaking solutions. The colloquium's title referred to a more fundamental question—*civil* timekeeping—although many presentation topics were somewhat esoteric and had little to do with *civil* timekeeping. Seaman suggested that we should first explore the design of the civil timekeeping system before addressing the implications that design might have on leap seconds.

Storz commented that he was surprised by the magnitude of the relativistic rate difference between Barycentric Coordinate Time (TCB) and the terrestrial scales. Allen offered that TCB still keeps "*SI* seconds". Kaplan said that the figure he used for his presentation originated from Seidelmann and Fukishima.[3] He also clarified that the chart did not reflect what would happen if leap seconds were terminated; UTC would just continue parallel to all other terrestrial atomic scales, diverging from UT.

Malys noted that with regard to the issue of the definition of "civil timekeeping" and nomenclature, one misconception he had faced within the US DoD is that a redefinition of "civil timekeeping" would not affect the Defense Department, which does not see itself as "civilian". He therefore noted that terminology is important, and that terms can mean different things to different people.

If leap seconds are completely ignored, Tyson asked if humanity was supposed to wait until |UT1-UTC| is approximately 86400 seconds and then add an unscheduled leap day into the calendar? Seidelmann responded that there was a suggestion to wait until |UT1-UTC| was approximately an hour, but that idea had since been discarded.[4] He added that other suggestions had been offered, such as making adjustments at the end of each century, or making an adjustment whenever the difference reaches some other tolerance (such as a minute), but none of these schemes are contained within the proposal coming before ITU-R Radiocommunications Assembly in January 2012. Seaman quipped that the proposal to make adjustments at the end of each century goes well with Paul Gabor's discussion of celebratory days, where we invent renewed chaos at a predetermined epoch and have a big party.

Tyson was also willing to gamble that no software would be in use one-hundred years later, although some in the room were not convinced this gamble was a sure thing. Several people commented that they have familiarity with systems that are still operating software from the 1960's, which is approaching a half-century already. As a point of reference, Seaman noted that one of the Kitt Peak telescopes tracked backwards during their Y2K remediation tests because it was using code written in Forth from the late 1960's. Tyson noted that bugs are fixed all the time in software, so fixing bugs should not be a concern. Kaplan clarified that the effect of UTC redefinition on software is not a bug in the usual sense of someone having coded an isolated mistake. It is also unlike Y2K where mistakes and fixes can be rather obvious; rather, UT1 ≈ UTC could be an undiscoverable working assumption. Variables may be generically called "UT" in

software and clear distinctions are often not made. Kaplan also raised a point about NORAD two-line orbital elements having an ambiguous time scale. Mark Storz replied that for the SGP-4 theory commonly used today, there is an assumption that UTC is approximately UT1.[*] Kaplan continued that the issue is therefore hidden and there might not be a comment anywhere that discloses the assumption that UTC ≈ UT1 in code; the programmer may not have even appreciated that there was a difference.

Because the issues seemed to be limited to mostly astronomers, Tyson asked what the worst scenario could be. Kaplan said that, for problematic astronomical applications, things would slowly go awry. Frank Reed said that this should only result in some additional programming work that might take a little while to discover, but all problems would be eventually discovered and fixed. Kaplan agreed that the issue creates job security for programmers.

Tyson said he liked the idea of making adjustments to the end of each century, because most people don't live that long and therefore people would have to deal with the problem either once or never. However, Seidelmann added that software is being written all the time so it is not simply a once-per-century matter. Tyson said that the foresight offered from an agreeable adjustment plan allows software designers to take anticipate centurial adjustments, and the knowledge that something will happen at the end of the century puts everyone halfway there. Seago responded that the leap second was introduced 40 years ago, and now we are talking about removing them because they were not universally adopted. He said there is a real risk that very long-term adjustments may not be reliably implemented regardless of planning. The issue with any long-term adjustment scheme is that our posterity may not agree to it or may realize it improperly. Tyson countered that the Gregorian calendar has worked well since 1582, but Seidelmann offered that a major software company incorrectly programmed the year 1900 as a leap year and still maintains the error for compatibility.[†]

Seidelmann added that the discussion point could be turned the other way: because we've had leap seconds for 40 years, everybody should already know about them and therefore they shouldn't be a problem now. Terrett said that they are a problem nonetheless in practice, as all sorts of software, including computer operating systems, do not deal with leap seconds properly. Tyson therefore asked what has happened with the two dozen leap seconds so far—do operators accept failure or do they retrofit the programming once failures are noticed? McCarthy said that some systems simply shut down before a leap second and restart afterward, rather than risk any failure, which is the easiest approach. Seaman likened this to a finicky pressure valve: an occasional restart seems to release a little bit of pressure and thereby introduces only a small amount of chaos every few years. However, alternative schemes allow increasing pressure to build up.

In response to Tyson's question about the worst possible scenario, Malys clarified that this issue not just limited to astronomers, but also affects the defense communities. If the issue of UTC redefinition is not properly understood and dealt with, he said the worst possible scenario is that critical systems could go off-line, such as missile warning systems. Tyson said that astronomers shouldn't focus on their own consequences if the issue also affects missile warning or other defense capabilities, because safety of life is a much bigger concern. Kaplan said that we still should not assume that most astronomers are aware of the issue and will know how to deal with it.

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[*] *Editors' Note*: General-perturbation theories for artificial satellites predate the creation of UTC with leap seconds.

[†] *Editors' Note*: Quoting Microsoft Support Article ID: 214326 (URL http://support.microsoft.com/kb/214326), "Although it is technically possible to correct this behavior so that current versions of Microsoft Excel do not assume that 1900 is a leap year, the disadvantages of doing so outweigh the advantages."

David Simpson expected software developers in the year 2075 or 2080 to not think about what will happen in the year 2100; just like today, their focus will be to address more immediate problems. Also, they may not expect their software will still be in use 20 years into the future. Tyson commented that such software might very well become entrenched as other code becomes built around it.

Returning to Tyson's queries about leap days replacing leap seconds, Reed foresaw a potential civil issue if a situation existed where, say, a Saturday could turn into a Sunday. There were only about 440 people who replied to the IERS Earth Orientation Center survey, but outrage would result if an internet survey asked "Is it okay for science to turn Saturday into Sunday?" Tyson noted that the power to change everyone's perception of the name of a day of the week would be extraordinary, as that convention follows no other measure except mutually agreed tradition. Reed agreed that the seven-day week is a really big deal, not just for the general populace but for millions of faithful across the globe. Reed said that matter is really a fundamental issue; if an adjustment is not applied then the reckoning by the calendar and the days of week will become jeopardized. Allen suggested that particular issue seemed to be beyond the ability of this meeting to address. Reed clarified that it is simply a fundamental point of debate that will get the attention of people that might not otherwise pay attention. Allen quipped that riots would still not erupt.

Tyson enjoyed the earlier discussions regarding cultural significance for the reckoning of time, but noted that today's culture is not strictly agrarian or overly concerned about whether the celestial bodies will suddenly depart their courses. If time is to be considered within the service of today's culture, then the most susceptible activity seems to be the programming of computing devices that run modern society. Like it or not, that activity has decades of legacy code embedded deep within it, some of which is inaccessible or compiled so long ago that it could not be recompiled even if the original high-level code were still available. These operate as black boxes. At some point there needs to be recognition that this is the way we run our world today. Allen said that his presentations would also address some of these issues.

Rots noted that the application of daylight saving time is often deliberated, but its existence is evidence that elements of society prefer to correlate their clocks with the time of sunrise. McCarthy said that China was a notable exception to this hypothesis. Tyson asked for clarification. McCarthy said that "China has six time zones compressed into one." McCarthy asked what percentage of the world's population "lives in a single time zone which essentially takes the space of six," and yet "they somehow have learned to live with that" situation. Tyson noted that his wife was from Alaska, where the variation in daylight hours over the course of the year far exceeds one hour. He was surprised that anyone there would even care about daylight-saving-time adjustments at that latitude; its practice there is hardly noticed. Tyson asked McCarthy if the example of China was also an argument to put the entire United States onto a single time zone. McCarthy said that he was not aware of any such arguments within the USA. Kaplan said that the Chinese might complain about their situation "if they could", with others agreeing.[*]

Reed noted that Percival Lowell proposed that the world should adopt Greenwich Mean Time globally as far back as 1915, so the idea of maintaining the same time over a large area is not new. Terrett said that there have been proposals to consolidate all of Western Europe into a single time zone; presently Portugal is based on UTC / GMT, while the rest of Western Europe (excluding the UK) is one hour later.

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[*] *Editors' Note*: The borders of mainland China span from about 73.5° E to 134.8° E, or about four hours. Before 1949, China employed 5 time zones.

REFERENCES

[1] McCarthy, D.D. (2011), "Evolution of timescales from astronomy to physical metrology." *Metrologia*, Vol 48, p. S138.

[2] Petit, G. (2004), "A New Realization Of Terrestrial Time." Proceedings of the 35th Annual Precise Time and Time Interval (PTTI) Meeting.

[3] Seidelmann, P.K., T. Fukushima (1992), "Why new time scales?" *Astronomy and Astrophysics*, Vol. 265, No. 2, pp. 833-38.

[4] Beard, R. (2011) "Role of the ITU-R in time scale definition and dissemination." *Metrologia*, Vol. 48, p. S130.