DISCUSSION CONCLUDING AAS 11-672

Ken Seidelmann's ended his presentation with a list of proposed actions, suggesting these as an alternative approach to addressing the issue of UTC redefinition. Steve Allen thought that Seidelmann's proposal to first seek consensus among standards and scientific organizations and national governments was similarly proposed back in 1969 before leap seconds were introduced, but the International Radio Consultative Committee (CCIR)[*] ignored that proposal back then too. Seidelmann disagreed, replying that the CCIR officially consulted various organizations and modified their proposals based on the technical feedback received, the result being driven by different scientific requirements.

David Simpson observed that the *status quo* didn't seem to present any imminent problem. Perceived concern over two leap seconds per year is a situation which is not likely to occur for many decades. Seidelmann agreed.

Rob Seaman said that he has not seen much discussion about Seidelmann's point that DTAI, UT1, and UT1-UTC should be made more readily available. Seaman remarked that if we stop the current convention where UTC ≈ UT1, there is no obvious infrastructure currently in place to make up for that lost functionality. If we start focusing on the future infrastructure needed to deploy these now, it should become obvious that applications can switch to the scale most appropriate for their application in the future. Seidelmann recalled a paper whereby the author was interested in a uniform time scale and the availability of DTAI would have been useful for his application. Seaman asked Seidelmann to explain what he meant by "DTAI"; Seidelmann responded that DTAI meant TAI-UTC, an integral value [currently 34 seconds].

George Kaplan noted that DTAI stays constant for long periods, but Seidelmann replied that software developers could benefit from monitoring a broadcast value that could be used to convert the broadcast scale UTC back to TAI whenever necessary. John Seago suggested that the broadcast availability of DTAI and DUT1 seemed to be a telecommunications issue, yet the proposed ITU-R Recommendation 460-7 no longer supported the broadcast availability of either DTAI or DUT1. He mentioned that the broadcast of DTAI had been explicitly recommended for the past ten years, already being written into Recommendation TF.460-6. David Terrett suggested that the reason why DTAI is not broadcast is because of its peculiar behavior; because it changes instantaneously that instant must needs be known in advance. Seago replied that characteristic seems not much different than broadcast UTC with leap seconds.

Dennis McCarthy said that he would really take issue with any claim that DTAI, UT1, and UT1-UTC are not readily available. He admitted that UT1-UTC could be made *more* available, but it wouldn't become more available until people *wanted* it to become more readily available. McCarthy said that his colleagues from NIST have found no users of broadcast DUT1, and they are seriously considering stopping its broadcast. Seago wondered if there might be more demand

[*] *Editors' Note*: The CCIR is the predecessor of the ITU-R.

for transmitted UT1-UTC if its value were allowed to increase to the point of being non-negligible. McCarthy replied that we cannot think about now; we must think about ten years in advance when people will be presumably much more automated and electronically capable, and "this stuff will just be out there." McCarthy said that DTAI is already in bulletins right now and there is no need to broadcast it because it doesn't change every day.[*] Allen suggested that ΔLS in GPS signals already provides a means of acquiring DTAI and knowing when it will change.

Daniel Gambis said that if UTC is redefined, then TAI may be officially suppressed at some point in the future and the BIPM would be in full charge of UTC. Allen clarified that the suggestion to suppress TAI originated with the Consultative Committee for Time and Frequency (CCTF). McCarthy responded that the CCTF "has not been totally in favor of that" suggestion. Allen clarified that written language exists which admits that the CCTF "would consider" suppressing TAI, adding if that possibility looms, then there is no motivation to invest in an infrastructure to broadcast DTAI.[1]

McCarthy said that the suggestion of using GPS time is very unacceptable to the precision timing community because GPS time does not meet national standards for precise frequency because the frequency of GPS clocks is changed, or, steered. National frequency standards with too much frequency variation are not allowed to contribute to the formation of UTC. Seago offered that Allen was simply noting that DTAI could be backed out of a GPS signal. McCarthy clarified that he was referring to one of Seidelmann's points that GPS time could be used potentially for timekeeping purposes. He then added that when Coordinated Universal Time was redefined in 1970 there was no name change.

Seaman redirected the discussion back to civil timekeeping by noting that "99.9999% of the technologically mature clocks on the planet are layered on GPS" because GPS is the foundation of the network time protocol (NTP). Seaman argued that all of the discussion about alternative time scales doesn't mean anything unless such times can be delivered to the devices that need it, and "that genie is now out of the bottle." Allen added that engineers are very often satisfied with GPS time and do not care about turf wars between the IERS, BIPM, CGPM, ITU-R, *etc*. Steve Malys said that UTC is a convention that has certain characteristics, and it may be clearer to phrase the issue in terms of whether we are discussing a change to the fundamental character of civil timekeeping versus changing some standard for distributing time. GPS is readily available and there is every reason to believe that it will continue to be available as a time-distribution mechanism.

McCarthy added that UTC gotten out of GPS is not the same as GPS time. Seaman asked for clarification, to which McCarthy responded that GPS time is comprised from the clocks in the spacecraft and the GPS monitoring sites to create a time scale internal to that closed system. Malys added that the system is not quite closed, as GPS clocks are steered to track the rate of UTC. Seaman did not understand why UTC from GPS is acceptable, but GPS time is not acceptable. McCarthy added that there are corrections broadcast within the GPS signal that allows one to get UTC from GPS time; receivers can apply this correction in order to recover accurate UTC. Allen questioned whether the most common devices that get time from GPS signals actually implement these corrections fully. McCarthy suggested that these corrections are applied automatically, but then said that it does happen from time to time that people confuse GPS time and UTC—even within the US DoD. He had heard "anecdotal stories of planes on the deck of an aircraft carrier being 34 seconds apart in time." David Simpson wondered why there should be a

[*] *Editors' Note*: The discussion concluding AAS 11-676 adds to this point.

difference of 34 seconds.[*] Seago noted that the cessation of leap seconds would not remedy confusion between UTC and GPS time. McCarthy clarified that his example was offering evidence that GPS time is sometimes confused with UTC via a GPS receiver. Seago replied that the addition of leap seconds combats that confusion by making the differences noticeably obvious. McCarthy rebutted that a 34-second difference is "good enough".[*]

To Simpson, it seemed that GPS time is less rigorously defined. Neil deGrasse Tyson agreed, who remarked that if one must index UTC to GPS time, then that step justifies a certain lack of confidence in GPS time. McCarthy replied that GPS time is monitored continuously, and corrections are provided to the GPS master control station so they can be uploaded daily. Seago asked if McCarthy could comment on the size of the corrections being discussed. McCarthy said that he thought the specification was 1 μs, but in practice the corrections were much smaller, probably on the order of tens of nanoseconds. Malys agreed that the corrections were much smaller than 1 μs. Seago therefore wondered how many people outside of metrology worry about that level of distinction. Seidelmann added that he thought some laboratories gently steer their own local realization of UTC(k) to minimize their difference relative to what they expect TAI to be. McCarthy said that GPS time provides a means of time transfer by being a common source for comparison of frequency standards.

Storz said that if DTAI becomes static and if leap seconds go away, then that would "be a big problem" for his organization (Air Force Space Command). His organization had been entertaining an idea of cloistering their systems together and running an atomic time scale that continues to track Universal Time to within one second, if UTC is redefined. They would therefore need to provide those systems with a "classic DTAI" that changes. Seidelmann said that if leap seconds cease, DTAI will become constant. Storz reaffirmed that his systems would still need a DTAI that represents the offset between TAI and "classic UTC"—a time scale that stayed within ±0.9 seconds of UT1. Allen said that if the current ITU-R proposal is adopted, no agency will be responsible for announcing when leap seconds ought to occur.

Storz said that he had been under the mistaken impression that some agency would still announce when a leap second opportunity *should* occur, even if those leap seconds were not going to be utilized by UTC. Rots said that the same information would be reflected in the growing value of UT1-UTC. Storz replied that his systems cannot handle a value whereby |UT1-UTC| is greater than one second. Allen said that no one will be providing that and Storz agreed that they would have to do it themselves. Rots suggested that the integer part of |UT1-UTC| could be applied to their "classic UTC". Storz acknowledged that they could do this but it would create additional software changes for their system regardless. Seaman envisioned a situation whereby different agencies would be performing these *ad-hoc* modifications differently: some might drop the integer part, other may round off. Storz realized that there was also a risk that they might provide data to external agencies relative to a time scale that no one else is using. Seaman said that, whatever the future holds, it "will be entertaining." Storz said it would be "a mess" and Seidelmann remarked that the situation offered "job security" for somebody.

Malys said that most people at the colloquium seemed able to present arguments that could favor the *status quo*. He asked if people "from the other side of the argument" were invited, as he was curious who those people were and what their arguments were. Seago said that the announced scope of the meeting was expressly focused to attract papers that might address adverse

[*] *Editors' Note*: The difference between GPS time and UTC in 2011 was only 15 seconds. The difference between UTC and TAI in 2011 was 34 seconds.

consequences of decoupling civil timekeeping and Earth rotation, because that area had not been well studied. Seago felt that most of the people in the room probably have some general ideas of the arguments favoring the cessation of leap seconds already, such as computer problems and telecommunications concerns, and the purpose of the colloquium was to present and discuss ramifications should UTC be redefined.

Allen asked McCarthy if there were descriptions of systems that have been shut down because of leap seconds, and the concerns about this, that could be distributed to help explain and answer Malys' concern about specific arguments favoring UTC redefinition. McCarthy said that a very interesting presentation was made at the US Naval Observatory by Poul-Henning Kamp, in which Kamp outlined some ramifications of continuing leap seconds.[*] McCarthy had asked Kamp how he had come into the information he was sharing, because it was McCarthy's experience that customers almost always say they have no problems with the insertion of a leap second. McCarthy hypothesized that there may be few reported issues because no one wants to admit that their system failed. McCarthy said that Kamp "gathered some of this information" and, while he may not remember the precise numbers correctly, he recalled that about one-third of the NTP systems that Kamp monitored "got it wrong" and that none of the time systems he monitored "inserted the leap second properly." McCarthy reported that Kamp presented a slide at the USNO "showing the times that when people were broadcasting during a leap second event" that the most common thing that appeared on his bank of receivers was *hang*, meaning they "failed to operate."

McCarthy said "one of the really scary things" that Kamp related was "a well-known system of air control within Europe in an unnamed country" monitors planes with a radar system which supplies information to a database. Another system reads that database and displays the information for air-traffic controllers. During a leap-second the two systems became unsynchronized such that "the air-traffic controllers were presented with the scenario at that airport one year previously. Although it was midnight, all the planes jumped and caused a great deal of consternation." McCarthy said that it was Kamp's contention that no air-traffic controller ever wants to say "I had a problem during the insertion of a leap second." We wouldn't want to say that all of the planes coming into LAX on December 31st were at risk—"that won't happen."

According to McCarthy, another problem that Kamp reportedly encountered was the complete shutdown of a production line at a drug company during a leap second because this particular company "requires time to advance" during its manufacturing. "So if time doesn't advance, something is wrong, and if something is wrong, the option is to shut down, so as to prevent an incorrect batch of drugs from being produced." Simpson said that the problem was probably due to the fact that they implemented an *ad-hoc* solution to the leap second, perhaps repeating the same second. McCarthy said possibly a time tag was repeated, or something hung, or "any one of these things." McCarthy had asked Kamp if any of the systems he had monitored broadcasted "23:59:60" and the answer was "one group did"—a Danish oil company.

McCarthy said that these stories are out there but they are almost impossible to document because they admit a failure that no one wants to confess; it would be too scary to let everyone know that they didn't do it right. David Terrett said he believed that it was common knowledge that most computers systems "don't handle leap seconds properly" and that "NTP as implemented gets it wrong" because people aren't managing the servers, *etc*. The question then becomes: "To whom does that matter?" To the vast majority of people now it does not matter. Terrett offered

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[*] http://phk.freebsd.dk/pubs/usno_slides.pdf (date 09-Oct. 2011)
http://www.usno.navy.mil/USNO/tours-events/usno-scientific-colloquia/time-from-microseconds-to-leap-seconds

that leap seconds also happen in the middle of the night for many people but McCarthy replied that leap seconds happen during the middle of the day in Tokyo. The argument that it also happens during a holiday also falls short whenever a leap second happens in June. Seaman said he would refrain from explicitly commenting on Kamp's stories, but noted that there is a phenomenon known as *confirmation bias* whereby we hear the evidence that supports our preconceived position more favorably than other evidence. The notion that "*absence of evidence* is not *evidence of absence*" cuts both ways.

To address Malys' original question about the announced scope of this meeting, Seaman added that there has not yet been significant exploration of the issues and risks from defining UTC. To Seaman, this matter seemed like a much more major change than simply dealing with technical issues surrounding a leap second every year or two. Seaman said it would be nice to have Kamp's air-traffic-control story in a place where it could be wrestled with. Yet, as scary as the story sounded, if a display jumps as described, then a mistake would be perceived. However, if things drift slowly off into areas where they are no longer correct, then that is potentially scarier to programmers because there is a risk of acting on incorrect data not knowing that it is wrong. Seago interjected that today's system of leap seconds was actually introduced to overcome concerns about air safety; specifically, air collision-avoidance systems proposed by the early 1970's were intolerant of frequency variations caused by changes in the length of the broadcast second.[2]

Seaman commented that, as a programmer, he is "spectacularly unconvinced" by arguments that, because some software was badly written, conventions must change so that programmers can continue to write software badly. Although the air-traffic-control issues seemed more fundamental, the consequences of the drug-company story were simply evidence of badly written software. McCarthy suggested that we are facing the same situation when we "complain about having to replace poorly written software now" if UTC is redefined. Seaman disagreed, clarifying that compliance with the existing standard does not make software poorly written. McCarthy offered that he was "sure that they [the drug company] wrote to their standards too," but McCarthy's main point would be that "any software that is more than ten years old should be changed anyway"—a point reportedly echoed from Kamp. After a long pause followed by disbelieving murmurs throughout the room, Seago jested that such a recommendation, if acted upon, would seem to personally benefit the software developers.

REFERENCES

[1] Wallard, A. (2007), "Consultative Committee on Time and Frequency Note on Coordinated Universal Time." CCTF 09-27, 3 September 2007.(URL http://www.bipm.org/cc/CCTF/Allowed/18/CCTF_09-27_note_on_UTC-ITU-R.pdf)

[2] Duncombe, R., P.K. Seidelmann (1977), "The New UTC Time Signals." *Navigation: Journal of the Institute of Navigation*, Vol. 24, No. 2, Summer 1977, p. 162.