ROUND-TABLE DISCUSSION OF MAY 29, 2013

In the discussion concluding the first day of the Colloquium on *Requirements for UTC and Civil Timekeeping*, attendees revisited issues and asked questions related to topics presented earlier in the day. The issues discussed included research studies based on time of day, historical terminology, leap-second representation, applications of proposed *Adapted Universal Time* (UTA), Earth's timekeeping in the distant future, the lack of available rationale for national positions, and issues surrounding more than one available timescale.

Returning to the issue of data archives, KEVIN BIRTH noted that fields of research—specifically field biology and chronobiology— have extensive archives of data that go down to fractions of a minute with UTC. However, most of the people involved are absolutely unaware of the leap-second problem or what is going on with the local timescale. DENNIS MCCARTHY asked if any of those biological databases care about one-second precision. BIRTH replied that he had seen chrono-biological studies precise to fractions of a minute; he was not sure if there was interest in maintaining precision down to the level of one second. ROB SEAMAN asked whether they use something that is just generally called 'Universal Time'. BIRTH replied that it is "generally UTC or GMT." SEAMAN continued that many ground-based observatories just use a "common vision of Universal Time" as an organized approached for common logistics. For astronomical archives, ARNOLD ROTS said it is obviously important when it comes to pulsar observations that any kind of interferometry needs accurate timing. MCCARTHY responded that those people are already very careful to make sure that they are using very consistent timescales.

BIRTH clarified that he was talking about an academic population that is not careful about any of these issues whatsoever. The issue is made all the worst because, when dealing with circadian rhythms, one is basically dealing with biological rhythms with respect to sunlight, and many of these studies do not bother to indicate the sunrise. Because many of them are working with animals near the equator, the researchers are sloppy and represent all these circadian cycles relative to UTC, without giving a record of when the Sun actually rose. BIRTH is unsure of the value of those kinds of studies if clock time drifts from the Sun if the leap second is done away with, but as a field they are currently unaware of these kinds of problems.

ROTS said that these studies have problems bigger than leap seconds; they seemingly require apparent solar time rather than mean solar time. BIRTH added that mean solar time is represented as UTC, but they are sometimes misinterpreting UTC as apparent solar time and are not taking into consideration the equation of time or realizing how flawed their data may be. DAVA SOBEL asked BIRTH about the fields which perform these studies. BIRTH said to think of a field biologist as somebody like Jane Goodall who goes out and looks at chimpanzees or baboons and then looks at her watch; that is the level of precision that is often taking place. However, chrono-biologists doing daily laboratory studies often use a precision that is less than a minute in their data sets.

KEN SEIDELMANN pointed out that a historic change occurred in astronomical timekeeping when a half-day step was introduced into almanacs in 1925.[1] In the 1960's, a well-known organization failed to take account of that half-day discrepancy while analyzing historic data, such that

their ephemerides were fit to observations different by one-half day for all data prior to 1925. SEIDELMANN said this error is an example of what happens when significant changes are forgotten. ANDREW MAIN said that the change in that case was actually obscured by the fact that the same term 'GMT' was redefined, which partly motivated promotion of the term 'Universal Time'. If people had just been clearer about it at the time, then at least for the people paying enough attention to use the correct term, it would all be clearer now. CHRIS TUASON said he did not follow MAIN's point about how 'Universal Time' came into use; he thought that 'GMT' was being used both before and after 1925 and that the term 'Universal Time' had not yet come into common use. MCCARTHY affirmed that the term 'Greenwich Mean Time' was in use and not the name 'Universal Time' at that time.

JOHN SEAGO suggested that, by introducing the half-day difference in 1925, astronomers were aligning their convention for 'GMT' to what everyone else was already using. In the context of civil timekeeping, the term 'GMT' already meant time-of-day measured from midnight to midnight, 'mean time' having been a legal standard for civil purposes at least since the 1880's. There was no half-day confusion as to what 'mean time' implied in legal or civil contexts; it was the astronomical definition of 'GMT' that was readjusted and thereby became confused. ROTS later noted that a difference of one-half-day was not just an astronomical tradition, but also naval. However, MAIN clarified that the naval tradition was a half-day from civil time in the opposite direction.

STEVE ALLEN said the same potential for confusion would exist after leap seconds are stopped; if a prospective customer is buying a system that claims to "conform to UTC", one is not sure if the manufacturer still knows what 'UTC' means. But if the name was changed to 'International Time' and the manufacturer then said the system "conforms to *International Time*," then one would know that the manufacturer understood that a change was made. So an advantage of a change of name is that one knows when he is dealing with someone who is at least aware of the issue.

To ALLEN's assessment, HARLAN STENN appended "…probably." A manufacture could notice that a new term is being used, and might start using that term even though they do not know what they are doing. MCCARTHY cited the example of 'GPS time' to mean "time obtained from GPS", whether that is the System time, or UTC, or whatever. There are people who will say that "all my time is *GPS time*" even though the time is UTC obtained from a GPS time receiver. SEAMAN responded that there is a static offset if Coordinated Universal Time is redefined; yet the slope just keeps going forever, whether or not we have leap minutes, or leap hours, or whatever, "it is quite forever."

Noting that the colloquium attendees had so far discussed background, terminology, and uses, JIM KIESSLING wondered if there is a compelling expectation for having a single timescale for all purposes. Instead, is it possible to bifurcate and propose a smooth, atomic-based time for timing applications (such as time hacks and so forth), and also something that is less elegant but more useful for conforming to astronomical applications that looks more like UT1 with some minimal error? ALLEN replied that the ITU-R must decide what shall be broadcast for its purposes, and how that will change the existing infrastructure using those broadcasts. The way things are structured, systems have to keep on going without breaking everything. In general, astronomers are always going to have a half-dozen timescales and nothing is going to change that.

KIESSLING asked who is actually using the ITU-R broadcast scale; STEVE MALYS generalized KIESSLING's question to ask whether the meaning of "broadcast" in the ITU-R sense includes Internet time transfer over, say, fiber-optic networks. Specifically, does the ITU-R as a radiocommunication entity consider network communication their domain? ALLEN said that because

the Network Time Protocol (NTP) and POSIX chose to use—or rather abuse—the name UTC, the answer is "Yes; they follow radio because they used the name."

SEIDELMANN thought it might be an ongoing argument at the ITU right now as to whether the ITU has domain over the Internet. MAIN said that argument was not at issue; NTP is maintained quite independently of the ITU, and if NTP made a poor choice by using UTC as its reference scale—"and it looks like it was a poor choice"—NTP might just choose to use a different scale in the same way that the ITU-R might choose to change what it recommends for radio broadcasts.

RUSSELL REDMAN thought the BIPM might still use radio broadcasts of time signals to coordinate between the national time services. KIESSLING said that would be a technical issue about coordinating various atomic times. REDMAN agreed, but regardless they would not be free to change that. And it still amounts to time broadcasting: there are receivers that can still be purchased to detect those service signals, and there is a lot of legacy equipment in use. MCCARTHY clarified that radio signals "are way too imprecise for time coordination" between individual laboratories and they are not used for that. SEIDELMANN said that the challenge today is how to precisely link the clocks in the laboratories for comparisons. Two-way time transfer is not quite up to that accuracy anymore, and certainly radio signals are not anywhere close to being satisfactory. One possibility is using optical fibers but even that has serious complications unless the fibers are dedicated for the purpose.

SEIDELMANN asked if the real problem with time stamping is that software cannot accept a value is over 60 seconds. MAIN replied that was a common problem, but it is just a matter of software to fix that part, which MAIN would address the next day while presenting AAS 13-518. REDMAN added that "software libraries that purport to implement UTC—don't" because they cannot represent the 61st second. SEIDELMANN said "it is just software;" he thought anyone should be able to write a piece a code that would allow a value to go over 60. MAIN responded that "you would be amazed to discover how many programmers cannot." REDMAN said that somebody still has to make the change, and if a big change is made that is not backward compatible, then this creates all kinds of problems for other people, "so you have to be really careful how you introduce that library and how you use it."

With regard to the UTA 'millistretch' proposal, STENN posed a hypothetical situation. Suppose a bank loans an individual "a *lot* of money"—to the point where the bank is calculating interest continuously. In this scenario, how would interest be calculated if the 'millistretch' was occurring at the end of day? For a very large amount of money accruing at a continuous rate of interest, STENN speculated that these additional milliseconds might be significant. CHRIS TUASON replied that one would just use the new definition of the day; unless one can get interest to accrue at a finer resolution than that, bank interest would be computed according to some definition of a day.

STENN said that continuous interest would be calculated based on "time interval" and if the amount of money is large enough, then adding milliseconds to the end of the day is "*real* money that people won't leave on the floor or give away." TUASON was surprised at the suggestion of an interest rate defined per second; he would have thought that a rate specification like "annual percentage rate" (APR) would capture the change. STENN said that the continuous rate is agreed to over time and one has to be able to calculate how many seconds there are over that time. MAIN said that interest is determined in units of days if one is talking about an annual rate. SEIDELMANN speculated that large, overnight loans between banks must be based on increments much shorter than a year, such as hours or seconds. STENN replied that "continuous interest" has finer granularity than 86400 seconds. TUASON suggested that the 'millistretch' would be accounted for when the finer granularity is calculated. STENN's concern was that the stretch is not known

ahead of time. GEORGE KAPLAN said such uncertainty already exists with the current system: one can take out a loan that goes past the end of the year without knowing whether a leap second will occur on December 31st.

MARTIN BURNICKI though that this sounded like an application desiring a number of leap *milliseconds*. TUASON agreed, saying that a rate defined in seconds would account for the fractional part by adding it in. STENN said this would have to be applied every day. TUASON agreed that it would complicate the interest determination if the rate is defined in seconds, but a daily determination would only need to happen if the rate is defined in terms of days or larger units. TUASON said that for somebody who pays a monthly rent, their effective rate goes up in February, and this would be same as with APR handling a leap second.

ALLEN noted that if this becomes important, then lawyers would need to specify the timescale in the contractual specifications; until someone decided that it needed to be specified otherwise, a day would be "86400 seconds". STENN said that if a day is no longer considered to be 86400 seconds, then this is a case that will need to be studied. ALLEN said that he was not sure that daylight-saving-time shifts were relevant to most banks; he would want to first see that aspect stipulated in contracts to know whether banks could handle finer increments. ALLEN was certain that there are a great number of financial calculations that assume every month as 30 days and 360 days in a year;[2] banks are already making massive approximations in places now and he was not sure than anyone is worried to that level. STENN said ALLEN's position would be an example of a case justifying the question "Most folks do not care about leap seconds, so why should we have them?"

KAPLAN replied that PAUL GABOR's presentation affirmed that there are quite a number of nations in the EU that do not refer to UTC in their basic definitions, but rather GMT, except we do not quite know what GMT is. The question is then, if leap seconds were dropped from UTC, would the new UTC be a sufficient approximation to GMT, because legal documents might refer to GMT. MCCARTHY said that should not be an issue, because there are defining instruments in each of those countries that, despite the name, give the legal folks a means to define the actual time. So whatever the name is, it is almost inconsequential. Such is the case in the United States, where regulations say that 'Coordinated Universal Time' is defined by certain standards for various purposes. KAPLAN countered that those developments are relatively recent, to which MCCARTHY agreed. KAPLAN asked if we know for a fact that every nation now has one of those instruments. MCCARTHY replied that GABOR "said it when I asked him [in the discussion concluding AAS 13-505]."

To provoke further thought, SEAMAN asked about what should happen over a *very* long timescale, when the tidal slowing of the Earth amounts to an increase in the length of day by something on the order of one SI second after 50,000 years. Will the Babylonians win out after 50,000 years; that is, will the fact that humans are accustomed to sexigesimal notation mean that the SI second will be redefined? Conceptually, what does one do when the physically different natures of atomic time and Earth rotation time must be reconciled? ALLEN said that the library of Alexandria did not have documents claiming to be older than 30,000 years. ALLEN's position was "we don't care; we are here to solve problems for deployed architectures right now, and we will leave that for them to deal with." KIESSLING also thought that it was reasonable to assume that one cannot speculate over a time interval longer than modern civilization has existed.

SEAMAN countered that one *can* speculate. The point of science fiction is not to think about *Star Trek,* but to think about the current world. There must be an answer to SEAMAN's question; what are the options? SEAMAN's answer to the question—one that he has maintained for the past decade—was that the second will be redefined if humanity continues to find itself in that circum-

stance. MAIN thought a better answer was that days will simply be more than 86,401 seconds long. Expressed in terms of leaps, this would mean more than one leap per day. This is not inconceivable; leap seconds could be introduced into multiple hours, for example. But at this point, it is more of a notational question than anything else and 50,000 years is plenty of time to resolve those issues.

SEAMAN reminded the group that the title of the colloquium was "Requirements for… *Civil Timekeeping*." SEAMAN really liked the exercise of designing wacky, *avant-garde* time systems; one could come up with even more bizarre options than "spelling the time."* But what is *practically* going to happen in the social context—in the culture—in such a situation? It is not enough to conjecture that posterity will just come up with "something else" as humans branch out into the solar system, as was done in the early stages of the conversation over leap seconds.† It is incumbent upon our generation to speculate on what that "something else" could possibly be. We cannot say "we will worry about it later;" we have to give our descendants something now that actually makes sense in the future on which they can try to build.

It struck BIRTH to be the more human thing to repeat our mistakes in the future, rather than fix them. BIRTH fantasized about a situation which engendered much laughter: mankind will get rid of the leap second now, and at some point the day will suddenly coincide again with clocks after tens of thousands of years. And then the people of the future will talk about the wisdom of those people of the 21st Century, and how the 21st Century was better connected to the spirit world than modern people and that they knew when the Earth was going to end…‡

MAIN said that if we are thinking "out of the box" to that extent, then it is not inconceivable that humanity might be able to alter the rotation rate of the Earth in 50,000 years' time to make it a more stable timepiece. This could bring the day back to the nominal 86400.000 SI seconds. MALYS wondered about how much energy that would take, and asked if anyone had ever done any calculations from meteorite impacts, because MALYS thought that the rotation rate of Earth could change measurably from a series of meteor strikes. Anticipation of where MALYS' question was headed brought the room into humorously raucous conversation. For example, TUASON said that instead of deflecting asteroids, Earthlings of the future would be concerned about aiming them precisely!

MAIN then mentioned that a specific analysis of MALYS's question was done by Randall Munroe of the webcomic xkcd.com in his "What-If" column.§ He examined what it would take to cancel out leap seconds by using meteorite strikes to affect the Earth's rotation. Munroe found that the amount of meteoritic material required would be rather devastating: "You might have a better timepiece, but you would not be able to live on it." MALYS said that the meteorite impacts do not have to happen on the Earth; they could happen on the Moon to change the momentum balance of the Earth-Moon system, because the slowing rotation of the Earth is tied to the momentum between the Earth and the Moon. MALYS therefore wondered if Munroe's analysis considered striking the Moon. MAIN replied that Munroe's analysis did not consider altering the Moon's orbit, although KIESSLING felt sure that we might not like that result either, because that is the lever-arm problem. MALYS said that another fantasy along those same lines would be to find an effi-

---

* *Editors' Note*: This is a playful reference to the proposed use of "letter-hours" (lours) per *Adapted Universal Time* of AAS 13-511.

† http://mm.icann.org/pipermail/tz/2000-July/010970.html

‡ *Editors' Note*: This is a reference to the perceived termination of the Mayan calendar on December 21, 2012, and popular speculations about this being an apocalyptic herald.

§ http://what-if.xkcd.com/26/

cient way to corral some asteroids to change the mass of the Moon or Earth—one would first have to determine how the mass would need to change.

MAIN said that a much more subtle and sensible approach would be to alter the circulation of the mantle. The currently observed decade-level instability in UT1 comes from the interaction of the core, mantle, and crust, and if we could learn to slightly modify the circulation in the mantle then we could potentially change the rotation of the crust using relatively little energy input. MALYS wondered if that could be accomplished by changing the ionosphere in some way; KAPLAN added in jest "if only we could gather up all the CO_2 and put it into space…" SEAMAN, having used a web browser to find the page containing the xkcd column, projected it on the screen for all to see, which generate a few final comments about the subject of altering Earth's rotation.

ALLEN asked REDMAN if there was anything that this meeting could produce that would be of use within the ITU-R arena. REDMAN said that he would personally like to get as many comments from as many people as possible to improve his proposed terminology and definitions. While REDMAN thought that the names he chose for defined terms seemed clear and obvious to him, he also felt that his suggested terminology seemed turgid and that people might not actually want to use those terms. ALLEN asked if REDMAN's paper should be distributed around the table to allow comments. REDMAN replied that his paper would be published as part of the proceedings, and that it would more useful for his email address to be available to attendees, so that he can receive comments. ALLEN asked if this would be for the purpose of providing input before ITU-R meetings in September 2013, which REDMAN affirmed. SEAGO said that the colloquium chairs could cooperate with REDMAN in getting his email address distributed and also his paper exposed sooner than the publication of the proceedings, if desired. MAIN also suggested advertising via the leap-seconds mailing list,[*] but SEAMAN feared that might be a punishing thing to suggest. REDMAN agreed that one must be careful when releasing draft material that may propagate.

KIESSLING asked if there was a concise rationale for the national positions of countries favoring a change to the definition of UTC via an ITU-R vote. REDMAN replied "Yes, but you may never find out what it is." The reasons why countries choose their positions are often well-hidden. Particular interest groups have the ear of particular branches of national governments, whereas other groups with very different opinions do not have the ear of their governments for completely unrelated reasons. KIESSLING concluded that the ITU-R thus has positions, but they do not have the rational understanding behind those positions. REDMAN replied "not that they will state publicly, or that you would believe."

TUASON wondered why the ITU-R decision-making process is organized along national borders instead of various technical camps. REDMAN replied that is the way the ITU-R is currently organized: nations join the ITU-R and send delegates. The delegates decide in advance what the national position is, and that is the position that they present. REDMAN recognized that "it is a flawed system in some ways" but "if you want to ask the permission of the world to make a big change, it is the *only* one we've got." SEAGO added that the ITU-R is chartered under the United Nations. Despite the fact that there may not be an official collection of positions, KIESSLING wondered if there was some understanding as to the rationale behind some of the decisions. REDMAN replied that "there are reasons they will tell you; you don't have to believe them." KIESSLING had "kind of dug into the U.S. position, and it is so wonderfully nonsensical that the only version is a memo," with none of its original advocates still working in their positions.

[*] http://six.pairlist.net/mailman/listinfo/leapsecs

TUASON asked if the ITU-R ever receives dissenting advice directly from the technical groups within specific nations (such as astronomers or geophysicists). REDMAN replied "Somewhat." Collecting information from other groups is part of the process right now. There have been various attempts to actively poll communities to find out what the public wants. And the answer is that the vast majority of the public has no idea that leap seconds are happening, no idea what the consequences will be, and their opinions are almost random. REDMAN continued that he personally queried his colleagues who were largely astronomers in Canada. To summarize the results of his informal and unscientific poll: "Every one of these guys could tell you in about half-a-second what the 'correct answer' is. Half of them will 'correctly' tell you that atomic clocks are infinitely better timekeepers than the Earth could ever hope to be, and therefore we should drop leap seconds and just get on with it. And the other half will 'correctly' tell you that human beings are diurnal animals and we must be up during the day, and any change in our timekeeping system which violates the general public's notion of what a 'day' is will be shot down on political grounds, and that is also true."

TUASON thought if there is a split in the astronomers' camp, and if the "computer side of the house was unified," then that seems to "make the decision." MCCARTHY did not think there was a split in the astronomers' camp. From having polled astronomers numerous times, MCCARTHY felt "most of them do not care" because most astronomers do not deal with issues of time. Both ALLEN and TUASON offered that astronomers could still have an opinion, even if they do not deal with time. SEAMAN did not think the characterization that most astronomers "do not care" was accurate, adding that "they want their telescopes to point." MCCARTHY responded that the "telescope pointers and the satellite analysts care, but they are an extremely small percentage of the astronomical community." SEAMAN replied that "the people who pay us do not want to pay us to fix something that is not currently broken." REDMAN agreed with SEAMAN's characterization. MCCARTHY said that, nevertheless, an overwhelming number of astronomers, say, 95%, just will not bother to respond to polls on this issue. REDMAN also thought if they were forced to guess, they would give it a "half-second analysis and then come up with a gut feeling."

SEAMAN replied that the biggest and most successful poll results so far were recorded in the 2011 Exton colloquium proceedings,[3] and "it is not what you just said. Many people responded, and many people did not want to change the *status quo*." MCCARTHY said he would "respectfully remain silent about that poll." SEAMAN replied "But these were responses from people; this was an effort that raised a response." ALISON PECK added the anecdote that it was announced at the National Radio Astronomy Observatory that she was coming to this colloquium, and "there was a huge number of people that pitched in with 'Don't let them drop the leap second!'" MCCARTHY suggested those respondents were "telescope pointers". PECK replied that "they were people who work at telescopes—astronomers." TUASON questioned whether that anecdotal opinion was really from a "vocal minority", which PECK could not answer.

ALLEN said that, on the other hand, in all the thirty years he had been with Lick and Keck Observatories, there was one instrument project where the Primary Investigator (PI) cared enough to actually specify the timescale to be correct; the others did not care to within five seconds when the exposures started and stopped. However, SEAMAN pointed out that the Time Domain[4] is the future of astronomy; it is certainly the future of optical astronomy, and it is "the present" with

LOFAR,[*] Gaia,[†] and a vast number of "very hot astronomical projects." The future of astronomy is not the historic plate vault that attendees toured at McCormick observatory the previous night. The future will be about rapid response to changing conditions in the sky.

KIESSLING explained the underlying reason for his earlier question about the rationale of national positions: it would be really nice to focus some of the work addressing the specific issues from the want-to-change community and the want-to-preserve community, such as how much work, and how many impacts, are facing us. ALLEN was not convinced that people who are happy with the agenda, and control it in the various nations, want to have that discussion. KIESSLING said that controversy for its own purpose—to generate a need for participant travel—is nice, but at the end of the day the *status quo* is very practical because less money is spent. However, REDMAN added that the *status quo* still requires money to be spent, because there is broken software that needs to be fixed. TUASON surmised that there already seemed to be some "balance of representation" in the room between the want-to-change and the want-to-preserve communities. REDMAN was unsure of the degree of "balance" but certainly opinions from both sides were being represented.

Continuing, REDMAN said that one of the problems with assigning costs is that, if leap seconds were suppressed, then after a while it would become apparent that there are a variety of applications that actually need time synchronized with the Sun. Right now those applications are not breaking because time is more or less synchronized with the Sun. These applications may emerge over the next fifty to one-hundred years; one by one something will break and people will wonder why, but right now those applications are unknown because they are not broken. What is known are the applications that are breaking now because people did not implement leap seconds correctly. Therefore "a wonderful collection of workarounds" is being maintained that tries to fix the broken software. This is actually another layer of broken software on top of the original breakage, which is becoming impossible to manage. Those issues are being found out right now and they are quite real and "the economic consequences are becoming nasty."

SERVANDO DIAZ therefore asked, if we searched all our broken software, and then all computers go forward minute after minute from now on, what percentage of systems would break? REDMAN said that would be a change at least as bad as Millennium or Y2K bug. He personally guessed that it would be a change at least as difficult as the switch from IPv4 to IPv6; it takes at least a decade to organize that kind of change and the level of effort that was needed for the Year 2000 is already known. REDMAN added that "you would have to go through and examine every chunk of software you've got to find out where the assumptions are built in, and I know that I have personally written stuff like that which is guaranteed to break." KIESSLING speculated that the situation could spawn an entire industry of consulting services. REDMAN said that "it is a very nasty issue, and it's one that we will have to dig ourselves out of one way or the other; no matter what decisions are made, we've got a lot of software to rewrite."

ALLEN surmised that there is a time limit on this. Already, one sees Google ignoring the ITU-R standard. The Advanced Television Standards Committee (ATSC) is saying that broadcasts in North America will be based on GPS time from now on. Engineers are saying "we can do this; we don't need you and we can do this our way." There is a limit at which too many engineers will have said "we don't care what your standard is anymore and are working this way."

---

[*] Low-Frequency Array for radio astronomy.

[†] *Editors' Note*: *Gaia* is an astrometric space observatory to be launched by the European Space Agency (ESA) as a successor to the *Hipparcos* mission from 1989-1993.

MCCARTHY thought that was a very likely scenario. REDMAN said they would be "voting with their feet." Even if they do not go to GPS, REDMAN guessed that the various large administrations around the world might make their own decisions if the ITU-R effort fails completely in 2015, and the UTC system will then be definitively broken. Furthermore, REDMAN was not seeing any signs of the large administrations contemplating a change in their positions.

SEAGO asked if applications were adopting GPS time because that scale was uniform, or because that scale was ubiquitous. REDMAN said the reason is because it is available; it is a pragmatic choice but not necessarily the best solution. ALLEN simply declared "It works" and KIESSLING immediately agreed that it is hard to fight with that. REDMAN added that one of tricks with GPS is that it is a positioning system; it was never intended to distribute time. MAIN interjected that time distribution was actually one of the design considerations; it would "deliver time to within some frighteningly small bound." REDMAN clarified that it was more important for GPS to get the position right than to distribute precise UTC. KIESSLING noted that ultimately the timing quality is inseparable from the position accuracy; STENN added that one cannot figure out location without knowing the time. REDMAN again clarified that GPS time is internal to that system and was not originally intended to be broadcast as a timescale for everybody else to use; one can obtain good positions with GPS as long as GPS time is internally consistent.

SEAMAN thought this raised an interesting question: supposing that UTC is redefined, what happens to the prime-meridian system and the definition of the day as something tied to the calendar? When "time" starts skewing relative to the Sun, what becomes of the definition of the day and the meridian system of the planet? MAIN said that the definitions necessary to understand that system already exist, and wider understanding is needed now. The general public lacks appreciation for the fact that there are multiple timescales and the need to deal with multiple timescales. Thus, it is ultimately an educational issue.

KIESSLING asked if it is too much to expect to have one timescale for all purposes. MAIN replied that it is too much; different applications have different requirements and there is a need for multiple timescales. STENN added that it is not possible to get everyone to convert to one scale. DIAZ asked if society could live with three or more available timescales. REDMAN remarked that we already have. Every time zone is a different timescale; we have dozens of them and we use them as appropriate. REDMAN does not see the difference between using TAI and using UTC personally; it is the same thing as using Pacific Standard Time versus Eastern Daylight Time. As long as one is explicit about the scale in use, it is absolutely clear. One should let the application determine which timescale is to be used and then choose the timescale that is appropriate.

At that, DIAZ asked if we could then just go back to the "natural second" for the application of time of day? MAIN replied that UT1 could be used for that, if one wanted. It is already available; it is just not quite as convenient to realize on a computer. REDMAN added that it also depends on how it is to be used and whether it is to be broadcast, because the tuning of oscillators requires the availability of SI seconds of constant duration. But REDMAN otherwise agreed that the SI second is just a standard. As a physical standard, it does not matter what the SI second is; its definition will likely improve over the coming decades and centuries but nobody will care that it gets even better and better.

BIRTH thought that, from the perspective of much of the public, the original ITU-R Study Question[5] was a bit flawed, because the Study Question emphasized a "globally acceptable" timescale, when it seems like the issue is really about the most "globally available" timescale. That would be the default timescale for much of the public that does not think much about such things, the timescale that comes down to their cellular telephones or whatever else. BIRTH thought that is what needs to be considered, not what experts find agreeable but rather just what people on the

street find available. SEAGO thought the original wording of "globally acceptable" in the Study Question was intentional. BIRTH agreed; rather, he clarified that it was a bad question for the situation. KIESSLING wondered if the Question was intentionally worded so as to create controversy, which BIRTH did not rule out. TUASON parenthetically asked about the wording of the title of the Exton Colloquium *Decoupling Civil Timekeeping from Earth Rotation*; he found himself "scratching his head" because "it seemed like decoupling was implied as the answer." KIESSLING replied that, based on the formulation of the draft ITU-R Recommendation at the time, decoupling would have been the implicit outcome if the draft Recommendation had been adopted in 2012.

REDMAN thought that a more interesting question was raised by SEAMAN about the definition of the word *day*. REDMAN thought the technical issues with timekeeping could be solved pretty much within the group in the room using TAI and UTC as they current exist, and a few more people to actually implement things. Between those things, and the obvious things like time zones, the problem is solved. But, if a uniform referential timescale is created and this scale starts to have legal effect, then the definition of the day changes. REDMAN admitted that he is not concerned about what will happen in 50,000 years, but he is concerned about political blowback now if a change is made that violates people's sense of what a day is. The sheer ridicule that would result from that could be politically dangerous.

KIESSLING said he was less concerned about the ridicule, and more concerned about contractors who have problems with their current government contracts. "Time" is fundamental to all contractual documents, and contractors would use the redefinition of time as an opportunity "to get well at the taxpayer's expense." REDMAN agreed, saying that all the social, economic, and political concerns are actually much bigger drivers to be concerned about than the technical issues of trying to decide whether to use TAI or UTC. These concerns are almost impossible to quantify, as far as REDMAN has been able to discern, because nobody will admit that their company was put in jeopardy.

SEAMAN noted that there is a recurring talking point that this is not a technical issue; however, it is a technical issue because there is a lot of astronomical software, space software, and presumably defense software that assumes that UTC and Greenwich Mean Time are roughly equivalent, and things will break. SEAMAN suggested that we should not necessarily assume that they will break one at time or in such a fashion that is always evident to people. As an engineer, it seemed to SEAMAN that the planning for those things should occur before a decision is made. REDMAN agreed "absolutely"; we should at least be aware of the potential for things to break, and be prepared to take steps. Being casual about it is wrong. SEAMAN added that when he did the inventory of the software package over which he was the "Y2K czar", there were ten times as many modules that were affected by search words such as "UTC" and "Universal Time" versus Y2K-specific search terms like "19". This is "not a minor issue in the Y2K-sense."

REDMAN said that there is one group for which he does not have a great deal of sympathy. Astronomers do complain a lot about this, but REDMAN has bought into the principle that an observatory should get tables of Earth-orientation parameters from the IERS to implement UT1 more accurately as soon as they can afford it. From his experience with the Lick and Keck telescopes, ALLEN said that "as long as a human is driving it, you don't care;" it is only the robotic systems that care. REDMAN said that observatories are moving closer to robotic systems. The Anglo-Australian observatory was one of the first ones where an operator could type in position coordinates and the telescope would slew to the position, settle down, and the object would simply disappear into the aperture so that all the light went into the instrument. Before that, there were always offsets that needed to be put in. The precision expected from these systems today is much

better than it used to be, so "if you can get UT1 right, just do it." SEAMAN said that very many ground-based observatories are already robotic, and in space they are all robotic. PECK said that in radio astronomy, particularly interferometry, they do not operate with offsets.

MALYS thought it worthy to consider the progress that has happened since 1972 using UTC defined with leap seconds. The invention of GPS has been highly successful. The Internet is operated all over the world successfully. Cellular telephones are now ubiquitous. And although there may be an occasional glitch, in general things have been working without any real difficulties. MALYS wondered: "At the 50,000 foot level, what problem are we trying to solve?" Is it to fix the occasional glitch? Or is it that somebody is using software that does not handle time correctly? In the bigger scheme of things, technology has greatly advanced within the past few decades, with precise timing being at the heart of much of it.

KIESSLING asked if MALYS's question meant "the tail is wagging the dog." MALYS replied that he was not sure of the problem needing to be solved. "If there is an occasional problem with a particular piece of software, we know that can be fixed." SEIDELMANN predicted that within the *next* forty years, improving technology will almost certainly force bigger changes to timekeeping conventions and protocols than what is being discussed right now. Current efforts seem to be trying to solve a problem that is not ready to solve. SEIDELMANN could not predict what major issues might exist in forty years, but once it becomes obvious that major changes need to happen, that would be an opportune point as which to consider timekeeping issues of broader scope.

DIAZ agreed that, given enough time something would come out that either gives a solution or makes it even worse. KIESSLING noted that delaying the decision is a "self-forming solution". MCCARTHY and TUASON replied that has been the current course. REDMAN feared that "not doing anything eventually does something, because people will run off and invent their own solutions, and then we could end up much worse." REDMAN said that it is better to have *some* decision than to not have any decision and let the system disintegrate. "Benign neglect is in fact not benign."

REFERENCES

[1] Sadler, D.H. (1978), "Mean Solar Time on the Meridian of Greenwich." *Quarterly Journal of the Royal Astronomical Society*, Vol. 19, pp. 290-309.

[2] Brown, P.J. (1998), *Bond Markets: Structures and Yield Calculations*. Fitzroy Dearborn Publishers, Chicago. pp. 6-9.

[3] Gambis, D. (2011), "Results from the 2011 IERS Earth Orientation Center Survey about a Possible UTC Redefinition." Paper AAS 11-668, 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. 123-79.

[4] Griffin, E.R., R.J. Hanisch, R.L. Seaman (eds, 2011), *New Horizons in Time-Domain Astronomy*, Proceedings of the International Astronomical Union (IAU) Symposium S285. (URL http://dx.doi.org/10.1017/S1743921312002499)

[5] Jones, R.W. (2001), Question ITU-R 236/7, "The Future of the UTC Time Scale." Annex I of ITU-R Administrative Circular CACE/212, March 7, 2001.