CONCLUDING ROUND-TABLE DISCUSSION OF MAY 30, 2013

In the discussion concluding the Colloquium on *Requirements for UTC and Civil Timekeeping*, attendees asked parting questions and expressed thoughts related to topics raised during earlier presentations and discussions. The issues discussed included non-technical timekeeping nomenclature, short-term and long-term ΔT behavior, time-signals and its recipients, future timekeeping technologies, the timekeeping role of GNSS, and the politics of time.

JOHN SEAGO opened the concluding round-table discussion by asking for additional input regarding PAUL GABOR's suggestion of technical versus non-technical uses of timescales within international documentation translation services. ANDREW MAIN said that he thought the issue was largely an educational one. There is now a group of well-defined terms for various timescales—terms which are not incompatible with usage by non-technical people. Rather than blindly referring to 'GMT' (or 'UTC' as often happens now), MAIN thought that people should be taught to reference 'UT' when being unspecific. Many uses of 'UTC' by non-technical people have no relation at all to leap seconds, and they need to be educated. STEVE ALLEN noted that the FITS I/O software library for writing FITS files is constrained to write the date keyword in terms of UTC, but because that is a POSIX-conformant library it actually writes 'UT' as the comment of what time is given, understanding that "Yes we are violating the FITS standard but this is actually what we are putting in the file because the computer is not giving us what is required." MAIN dryly replied "That's encouraging…" which engendered some quiet laughter around the room.

Noting earlier discussions that tried to draw a technical distinction as to whether 'Universal Time' refers to "the same time used all over the global" versus "a measure of the rotation of the Earth synonymous with mean solar time at Greenwich," SEAGO wondered which context a non-technical user would expect from the term 'UT', or if that mattered. MAIN thought that the term 'Universal' is not used in either of those senses outside the technical sphere, so he did not think there was a problem. Additionally, MAIN thought the term 'International Time' seemed perfectly clear from a non-technical point of view.

KEVIN BIRTH observed that the most common non-technical use of any of these timekeeping terms was in news reports referring to time meant for someplace else. If one looks at the variety of global media outlets, there are many that still use 'GMT'. SEAGO asked if BIRTH would say that the *majority* of media outlets still use 'GMT'. BIRTH contemplated the question, then replied that the majority of those he "had looked at" use 'GMT', but he was not comfortable concluding an absolute majority based on that.

ALLEN cautioned that a lot of dynamically generated web pages will time-tag the page to whatever the JavaScript library understands to be the name of the local timezone. "So you may see something different than what someone else sees." HARLAN STENN added that there is a

GeoIP library* that approximates the user's location based on the user's Internet Protocol (IP) address; however, the location of the user's internet service provider (ISP) does not necessarily correspond to the location of the user.

Regarding KEN SEIDELMANN's illustration of various estimates of ΔT, RUSSELL REDMAN noted that different parabolas resulted from the same data depending on how much weight was given to the ancient observations going back several thousand years. A steeper parabola results from stronger belief in the ancient data, which may be a better long-term estimate of how many leap seconds will be needed eventually, but this does not actually inform as to what is going to happen in the next fifty years. ALLEN warned that it is really bad to fit a parabola over any interval of time. REDMAN agreed that observed ΔT really does not look like a parabola; the parabolic model exists because people want to incorrectly assume a constant rate of deceleration of Earth rotation. MAIN wondered if the lack of fit was because ΔT has not yet been measured over a sufficiently long period. REDMAN thought this might be true in principle, but data will probably never exist over much longer periods; it almost surely requires actual human observations of astronomical events to tell us how the Earth was oriented. DENNIS MCCARTHY said that ΔT "certainly fits a parabola within the errors of the observations."

GEORGE KAPLAN thought that lunar deceleration was now known to approximately two significant digits; this would generate another independent parabola. MCCARTHY clarified that the parabola shown by SEIDELMANN's figure labeled 'McCarthy 2012' "is geophysical and is not observed"—it comes out of the IAU precession-nutation theory. SEAGO was unsure that the deceleration value was based purely on lunar theory after consulting the reference from which the value was adapted; as evidence, SEAGO noted that the shape of the 'McCarthy 2012' curve was rather close to the empirical fit attributed to 'Stephenson and Morrison'. MCCARTHY clarified that the value was still based on geophysics, rather than mathematics.

STEVE MALYS asked what the geophysical interpretation was supposed to be: what causes a change in slope before and after *c*. 1825? KAPLAN said that the Moon is moving away and it is a consequence of conservation of angular momentum within the Earth-Moon system. MCCARTHY added that it was a tidal deceleration: the Earth has a tidal bulge which precedes the Earth-Moon line, and the Moon pulls back on that tidal bulge and acts as a brake. MALYS asked why its character should be a parabola. MCCARTHY said a parabola assumes a constant deceleration which, if integrated twice, results in a parabola. SEAGO asked if MALYS was wondering why the observed ΔT is not smooth; MALYS affirmed that he wanted to know why a parabolic shape was supposed to result. MCCARTHY and SEAGO elaborated by saying that a parabolic curve was an outcome of the integrated effects of a constant angular deceleration. If a constant acceleration / deceleration is integrated once with respect to time, that results in a linear difference in angular velocity. If the linear rate is integrated again to obtain position, that results in a parabolic difference of angular position. UT1 is a measure of Earth's angular position, thus its behavior is expected to be parabolic, assuming constant deceleration relative to purely uniform rotation. MALYS found the latter explanations adequate.

SEAGO continued by saying "the shape of the observational data obviously indicates that the deceleration is not constant, because ΔT is not a parabola." Addressing REDMAN's point about the inclusion of ancient data, SEAGO said the figure of the Earth may have very well changed since the time of the ancient data; in that case one would not be dealing with a constant effect over time. So depending on how the ancient data are weighted, one gets a different shape and it be-

* http://www.maxmind.com

comes really unclear how much variation in the parabolic fits is due to temporally uncertain geophysical effects and how much variation is due to the observational uncertainty of the very early data. “This means that we just cannot predict [with a parabola] as well as we would like.”

SEIDELMANN asked why the minimum of a best-fit parabola should be around 1830—is that the mean of the observation set? MCCARTHY quipped that is the “magic date”. MAIN elaborated that is the midpoint of Newcomb’s observations which determined the conventional length of the ephemeris second, which became the basis of the SI second.[1] KAPLAN reminded attendees about a point which he made at the Exton colloquium, namely that there was “a fair amount of uncertainty” in the calibration of the atomic second to the ephemeris second.[2] KAPLAN recalled the uncertainty as being on the order of one part in 10^8 or 10^9, which is a pretty large uncertainty when discussing clocks. MCCARTHY said he was never able to understand how Markowitz came up with his calibrated number; MCCARTHY interviewed Markowitz for historical purposes[3] and Markowitz refused to give MCCARTHY an answer.

DANIEL GAMBIS said that at the same time there are opposite components which lead to acceleration of the Earth. GAMBIS’ presentation (AAS 13-522) touched on the melting of the ice cap, such that the Earth is rotating quicker, and in 1972 the length of day was 2 milliseconds longer than it is now. So it seems that the Earth is relatively accelerating and the number of leap seconds has been lessening in recent years, which may be fortunate for the next century. MALYS lightheartedly surmised that as the Earth continues to get rounder and rounder, future leap seconds may not be any problem. MCCARTHY jested this seemed like “an argument *for* global warming,” to which REDMAN chirpily added “…at least briefly.”

ALLEN said that if one revisits paleo-cretaceous studies, the geophysics show that the deceleration that goes into the $\frac{1}{2} a t^2$ term could not have been constant over hundreds of millions of years, probably because the friction of the tidal basin was probably very different with Pangæa than it is now. ALLEN considered plate tectonics and core motion and atmosphere all equivalent to geophysical “weather” over the very long term. KAPLAN also acknowledged that the Moon was closer then and so there could be a number of effects that contributed to very long-term variation. Toward ALLEN’s analogy to time as weather, MCCARTHY added that Earth-rotation data in the 19th century have been used as a proxy for meteorological estimates of the atmospheric angular momentum, thus turning the ‘weather’ perspective around.

REDMAN said that, when the decision is ultimately made between time scales for civil use, he hoped the decision will be made on the *actual* merits of the timescale and not as a ‘quick-fix’ for a software bug that people would rather ignore. As REDMAN previously demonstrated, there is a need to deal with the software problems to handle historic data, if nothing else. JIM KIESSLING asked if there was an implicit window on the validity of any timekeeping solution, considering that technologies change. Specifically, is there a desire to ensure a valid solution for, say, the next forty, or fifty, or one-hundred years? REDMAN did not think that one could accurately guess where technology would be forty years into the future. In the collection of definitions that REDMAN suggested via AAS 13-507, the terminology tried to avoid presupposition of particular technologies. This was one of the reasons why REDMAN did not like using the term ‘atomic timescale’. Right now atomic clocks are the best we can possibly do “but will that still be true twenty years from now?”

Toward REDMAN’s question, MAIN supposed that pulsar-based timescales might be better at providing long-term stability. However, REDMAN greatly feared the use of pulsars as timing references, because if the pulsar “goes glitch, then what?” MAIN said that multiple pulsars would be used, just as the celestial reference frame is based on a catalog. REDMAN nevertheless thought that our understanding of pulsars needed to greatly improve to be able to use them as clocks. “We can always build better clocks; we cannot build better pulsars." MCCARTHY affirmed MAIN's point that pulsar-based scales would only be useful over the very long term. REDMAN replied that "pulsars make a dandy case for checking that our clocks are sensible" but he "far preferred to keep clocks as clocks."

MAIN thought that pulsars will be needed as civilization advances to interplanetary navigation, which will be the future generations' equivalent of celestial navigation. REDMAN was skeptical, saying that there are "tons of ways to do that kind of thing, and quite frankly they will all have their own clocks on board, and communications with the Earth." KIESSLING noted that pulsars would not be necessarily used for timekeeping in the navigation problem, but as a directional waypoint. SEIDELMANN also offered that optical clocks will be a coming standard that will degrade the accuracy benefits of pulsar-based timescales.

SEAGO asked if optical standards presented an argument for 64-bit words in NTP. MAIN and SEIDELMANN replied with assent, while KIESSLING thought that 48-bits seemed sufficient. MAIN countered that "64 bits is so cheap these days there is no reason to use 48 for anything." NTP is already using 64-bits values in the form of 32.32 fixed point, and it is possible to perform arithmetic on that in a single cycle on any modern processor which has 64-bit words. Presuming that KIESSLING was proposing going to a 48.48 fixed point representation totaling 96 bits, MAIN said that representation would require two operations because there are 1 ½ words of data; once that is done there is no reason to not extend to two full words and have a 64.64 fraction.

ROB SEAMAN presumed that the conversations that have taken place within ITU-R Working Party 7A* had not resembled the technical conversation at this meeting, which was of concern to him. SEAMAN believed that Working Party 7A has had exactly the same intent during the many years it has been pursuing this issue. The engineering process being followed struck SEAMAN as being upside-down, and thus very risky: the process should start by reaching a consensus on the definition of the problem before deciding on how to solve it. SEAMAN suspected that such a Recommendation was very likely to pass because of politics, regardless of BIRTH's perspective that a draft Recommendation to cease leap seconds will not find international acceptance, and regardless of MAIN's perspective that a Recommendation to cease leap seconds would fail to take hold in response to operational needs.

SEAMAN did not understand the motivation behind the seemingly political goal to redefine UTC to be the operational equivalent of TAI. If UTC is redefined, the notion of mean solar time will still be a necessary notion, which might "breathe new life" into use of the acronym GMT. There will still be a need for the concept of atomic time, and a need for the concept of mean solar time. Thus SEAMAN thought this was a risky issue. Although planes have not crashed before, there seemed to be this "weird assumption that there are no risks with redefining UTC." However, SEAMAN thought that there would be significant risks, as well as significant costs. KIESSLING replied that there are risks with the *status quo*, and there are risks with changing the *status quo*. Does the cost and risk of change override the cost and risk of not changing? KIESSLING thought that maximum benefit resides with not changing UTC.

On the issue of clock synchronization, KIESSLING directed a question to MALYS as an expert in GPS. "If we consider GPS time as a time standard—not in and of itself such that we are going to discipline everything to it, but consider it a transfer standard that has some knowable error off-

* *Editors' Note*: Working Party 7A (WP7A), *Time signals and frequency standard emissions*, is the sub-group of ITU-R Study Group 7 responsible for formulating recommendations on the definition of Coordinated Universal Time (UTC).

set from an accepted definition of TAI— is that not how the contemporary commercial world is using GPS?" MALYS agreed with the premise that GPS is already used in the way described by KIESSLING, because GPS is well known, well tested, well publicized, trusted and reliable. KIESSLING therefore asked who are still the primary customers receiving UTC time signals via radio signals which fall under the jurisdiction of the ITU-R. Several national GNSS systems are expected to be available that are all going to attempt to disseminate traceable time based on the SI second, which allows synchronization of local clocks to the national standards with some quantifiable error. Is it really even necessary to consider radio dissemination, understanding that GNSS systems are no longer just a single national system? MALYS thought that there was nothing wrong with that approach but people from the time observatories would be better positioned to provide an answer to the question of who their customers are. It was only at this meeting that MALYS learned that U.S. and Canadian television broadcasts were already using GPS time synchronization, and that there are many other commercial activities that are using GPS for synchronization.

KIESSLING clarified that his question was broader: who still depends on UTC dissemination via radio broadcasts? ALLEN offered that the two clocks in Skip Newhall's movie* which displayed the leap second correctly were WWVB radio receivers. After the last leap second, those high-precision receivers could no longer lock onto accurate time because WWVB changed the signal modulation to be more suitable to reaching radio-controlled wall clocks and wrist watches. Thus "the broadcasts have changed who they are aiming at." MAIN agreed and added that radio-controlled watches and clocks are becoming steadily more prevalent among non-technical users. There is still a market for that. It is presumably a lot cheaper to receive a radio signal than to receive GNSS signals which require added computation. Shortwave signals also work indoors, which was a noted problem with GPS signals.

BIRTH noted the Orthodox Jewish community really likes radio-controlled clocks. He received reports of synagogues relying on them for accurate UTC to represent *zmanim*. SEAMAN asked if they called radio-controlled clocks by their marketing label 'atomic clocks'. BIRTH conceded that they refer to them as 'atomic clocks'. MAIN noted that manufacturers vary their marketing nomenclature. ALLEN further warned that manufacturers often put non-radio-controlled quartz clocks into the same cases as radio disciplined units, such that undisciplined clocks can be labeled as an 'atomic clock'. MAIN said the lack of radio disciplining of an analog clock should become obvious when it is started, because a radio-disciplined clock goes through a very interesting process of shifting the hands around after receiving one-minute's worth of signal. ALLEN replied deadpan that he spent a long time working with a clock that he "thought was going to do that— but never did," which brought the room to laughter.

To ALLEN's point, MCCARTHY noted that radio signals were difficult to receive on the eastern coast of the United States. MALYS then offered a clarification about the reception of GPS indoors. Many stationary facilities or permanent buildings will merely locate an antenna on the roof, which solves any signal reception problems; the issue is with mobile or handheld devices. MAIN replied that he applauds the availability of accurate time to non-technical people, but it is a bit much to ask ordinary non-technical consumers wanting precise time to install a rooftop antenna.

STENN said that he had heard that u-blox™ made "truly awesome" GPS receivers on the order of $30-$40 which seemed to have excellent indoor reception. He had not yet used one, but his discussions with owners suggested that they had worked thus far in every building tried. KIESSLING believed that if a modern GPS receiver did not work indoors, then the building must

* http://www.youtube.com/watch?v=CaOpGrs0x_U

be well shielded. MAIN conceded receiver technology had certainly advanced since he bought his first GPS receiver more than a decade before. MALYS said that advances in the antenna technology were primarily responsible for better reception.

REDMAN cautioned that the entire GNSS discussion was "something of a red herring" when considering the definition of UTC. GNSS is useful as a conduit for time distribution, but it is ultimately a channel and not a definition. The task under consideration is whether the *definition* of UTC is "right" and "useful". KIESSLING said this is why he had pointed out GNSS as a means of dissemination and coordination. REDMAN agreed that very often the discussion gets a little sidetracked with queries like "Why don't we all just use GPS?" 'Using GPS' is not a definition and it does not answer the question that has been asked.

Based on his experience, BIRTH did not think we had "a good handle" on who are the technical users of time. In some of the communities that BIRTH consulted, he encountered unexpected levels of technical interest. There is a tendency to think of this issue as a discussion among time experts of a particular sort, but there are other kinds of time experts out there about whom there is inadequate awareness, and there are consumers of accurate timekeeping that possibly have not been mentioned.

A topic of concern to MALYS that had not been discussed was that some nations within the ITU-R do not have atomic clocks. MALYS wondered if any decision to change to a purely atomic standard could alienate those countries. REDMAN noted that only fifty-five (55) nations maintain national time services, but he did not think the rest would be alienated. Rather, those nations would just use another nation's standard and thus they would be affected by any decision to change. MALYS responded that all nations have access to the rotation of the Earth as their common denominator, but REDMAN added that they also have access to time signals. While the signal might not be operated from within their own country, "they don't care for the most part; so long as it is a good one, they can still do business." In some sense, those nations without time services are freer to choose which signals they want to follow versus those nations that operate time services and therefore have something to protect.

MALYS raised another aspect that had not been discussed. Toward the definition of "time for the planet Earth," if civil timekeeping is moved strictly to atomic time then for the first time the planet would become entirely dependent on commercially produced products that only a handful of people can actually build. MALYS was not sure how many companies build frequency standards that operate at the precision of a national standard, but there would seem to be greater dependency on those commercial entities. However, KIESSLING thought that the ubiquitous nature of GPS has put society in a place where, by default, nobody cares about time standards except for a very small circle of experts.

REDMAN thought that situation had always been true; back when REDMAN started at the NRC, the press had correctly reported that Canada had four of the most precise atomic clocks commercially available at the time (*c*. 1984). The reason for having four was that one might occasionally glitch, such that two more were needed to maintain a stable reference, and another spare was needed in case one of the three required service. "These days, quite frankly, we are less dependent upon those experts now than we ever were before, because manufacturers can churn out cæsium clocks at an enormous rate, and anybody can buy one relatively inexpensively."

SEIDELMANN added that the U.S. Naval Observatory currently operates four rubidium fountains that are more precise and a better source of time interval than all the other clocks in the world: if only those clocks were used, a better timescale would result. REDMAN agreed that people were constantly pushing the boundaries of the technology, but nevertheless there was probably less dependency on the ultimate experts now than ever before. CHRIS TUASON asked why SEIDELMANN referred to a rubidium-based scale as a "better timescale", because it appeared to TUASON as being the same timescale. REDMAN clarified that the timescale may be the same but the actual clock was "way better". KIESSLING phrased it as "the 'minimum impulse bit'—if you will—got smaller."

SEAMAN observed that the keystone for the metric system is really the cæsium frequency; thus, he wondered about the implications if the best clocks are no longer cæsium based: is that analogous to the meter bar in Paris being different than a meter? SEIDELMANN repeated that he is betting that the SI second is going to be redefined. STENN said that he had asked Judah Levine of NIST about that, and his opinion was that one can never claim to have more precision than cæsium, because cæsium is the standard. Rather, one can claim that other types of standards provide "a more stable source of time."

ALLEN asked MCCARTHY how many stages of approval would be required to change the basis of SI second from cæsium and to another ion. MCCARTHY replied that the mechanism exists now to do that, and the CCTF* has already adopted a table of backward-compatible frequencies for many of the ion clocks. It was the subject of a CCTF working group to actually come up with numbers adopted at the last meeting of the CCTF. The others are compatible with cæsium-133 and promised to provide more stability than cæsium, but that had not resulted in an overall shift toward using another ion.

MAIN recalled ALLEN's question as not about what clocks are actually being used, but what is required to change the SI definition. MCCARTHY said that the General Conference of Weights and Measures (CGPM) would make the change, based on a recommendation from the CCTF with approval by the CIPM.† TUASON asked if the relative weighting in the TAI algorithms would change if the SI second was based on a different ion. MCCARTHY replied that those types of standards have yet to contribute to the formation of TAI; hydrogen masers, cæsium fountains, and rubidium fountains are the contributors. TUASON understood SEIDELMANN to have said that the USNO had switched to rubidium fountains. MCCARTHY clarified that the USNO had not switched the basis of their standard; it was still essentially based on cæsium fountains and hydrogen masers. ALLEN summarized MCCARTHY's response to mean that the CCTF had to make an actual recommendation, and the CIPM would approve that, and then the CGPM would approve that.

MAIN asked when the CGPM next meets. MCCARTHY was not sure, but there was an understanding that general conferences happen every five years, with CIPM and CCTF meetings happening more often. ALLEN described the various levels of meetings as "layers of the onion." MCCARTHY agreed, adding that higher levels of bureaucracy "get to the point where you know there are no experts in the building. They do not know what they are doing; they are just doing what people tell them." MCCARTHY admitted that this "is not a heck of a lot different than the ITU. The votes in the ITU are being done by people who don't know a thing about time."

For the immediate purpose, REDMAN thought that "the only actual contact that UTC has with the technology" is that it is defined as "the SI second on the rotating geoid. How the SI second is actually implemented is an irrelevancy to the definition of UTC. It can get better as often as it

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* *Consultative Committee for Time and Frequency*, which before 1997 was known as the Consultative Committee for the Definition of the Second (CCDS).
† *Comité international des poids et mesures.*

likes, in whatever way it likes, as long as it does not fundamentally change" the nature of the SI second. ALLEN said the question is what will be broadcast and thus translated into Internet signals. REDMAN agreed that was the question.

KIESSLING wondered why broadcasts should be translated into Internet signals when GNSS already provides an extremely functional world-wide distribution system with well-established time delays. MAIN replied that a GNSS approach requires specific hardware; it is much easier to roll out new software and thus new protocols than to deliver new hardware to every Internet user. ALLEN added, "It is also really hard to install new protocols and software on a lot of systems which are relying on the signals staying pretty much the way they are." REDMAN agreed that the signal works with the definition and that has to be figured out. However, considering the current pace of generational rollout of hardware, KIESSLING questioned the wisdom of deprecating the value of the low-cost time receiver; between the economics of programming time versus a piece of hardware, the hardware will win.

MAIN said that most people—KIESSLING being an exception because of his professional experience—would be amazed at how stupid companies can be, and offered an interesting parallel. Much modern programming requires a good source of random numbers, and to do this well requires hardware. The Linux kernel has some interesting software that tries to collect entropy from ordinary system events, but the rate at which it produces quality entropy is very low. The result is that programmers use appalling sources of pseudo-random numbers to preserve entropy. Plugging in a small piece of hardware that produces a high rate of random numbers for tens of dollars per host is much easier, and gives much better results. But hardly any companies bother to do that, and most instead try to solve the problem in software. MAIN supposed that perhaps this is because programming time comes from a different budget than hardware.

ALLEN asked if MAIN was referring to one additional component on the motherboard that would generate random bits. MAIN replied that while possible, there were certain technical problems with motherboard integration and it was much easier to purchase a separate component that could plug into a motherboard. REDMAN questioned the wisdom of having such a device too close to the motherboard. SEAMAN thought that it ought to be something that could be turned into a USB stick. MAIN replied that the one he prefers[*] comes as a USB stick, which can be mounted internally onto a motherboard equipped with a USB port for this sort of application. SEAMAN quipped that such a device could be given as a gift "for the programmer who has everything."

MAIN wondered how inexpensively a GPS time receiver could be made into the form of a USB stick small enough to connect to the motherboard, and also whether a computer case shields the reception of GPS signals. SEAMAN thought such a device might connect wirelessly if necessary. MAIN thought this may be potential market niche, so ALLEN asked MARTIN BURNICKI, "How cheaply could you make a GPS receiver?" BURNICKI lightheartedly replied, "Ours are not cheap." The little chips that are presently built into 'smart phones' are fairly inexpensive, but Meinberg relies on technology where an antenna can be set up several hundred meters away and those systems are more expensive.

KIESSLING said that depending on the price, one would also want to be able to synchronize to another external source of time for situations when GNSS signals are unavailable. MAIN noted that it was common for motherboards to routinely have quartz oscillators, although they are not especially good ones. Those may be fine for ordinary uses over short periods of GNSS signal in-

[*] http://www.entropykey.co.uk

terruption. The chip-scale atomic clock seemed promising but far too expensive to be put into every machine at the moment. KIESSLING liked using the processor cycle counts. MAIN said that when processor cycle counts first became available, there was a problem with laptops: when the machine was suspended it also suspended the processor clock and thus synchronization would be completely lost. Some machines now keep the processor cycle count running even when the machine is otherwise suspended.

In response to a final call from SEAGO for any additional questions or comments specifically related to the colloquium, TUASON asked SEAGO to clarify an earlier comment implying that air-traffic control was the reason for leap seconds (concluding AAS 13-523). SEAGO replied that the collision-avoidance systems of the 1970's needed unvarying frequency to function properly; "rubber seconds" caused the frequency spectrum to move around, so air-traffic safety was a primary motivator for having constant duration of unit in the broadcast time scale. REDMAN agreed that "rubber seconds were a bad idea for that."

KIESSLING stressed that it would be very bad engineering to design a real-time system operating air-traffic control radars to care about real-time UTC and leap second insertions. Such systems should be tied purely to the system clock and reporting out asynchronously; there is no reason for a real-time measurement system like that to know or care about leap seconds. REDMAN said that external references through radio, *etc*., are still received to provide a stable signal. KIESSLING suggested that might be a proposition for pure GPS time which is still independent of leap seconds. REDMAN thought that the actual synchronization issue back then might have been more with the manufacturing sector rather than the real-time operations, because back in those days especially high quality clocks were needed. KIESSLING's point was that real-time operations are insensitive as a general rule to these issues; it is when there is some kind of power interruption or other catastrophic event to the real-time operation that there is reliance on back-up systems.

KIESSLING raised his earlier question as to "why software people have this bizarre tendency to work in base-60, other than just history." REDMAN did not think that software people should be blamed for the last four-thousand years of timekeeping history; they are simply reproducing what others initiated. As a software person, MAIN playfully asked why GPS maintains base-60, and base-7, and "all of the other bases it uses" in its signal. KIESSLING acknowledged that GPS uses counts of GPS seconds and GPS weeks.

The question led TUASON to ask why UTC-SLS spreads the effect of a leap second out by 1000 seconds versus some other value. MAIN replied that one would have to ask Markus Kuhn[*] to be sure, but MAIN thought the objective was to make it easy to specify the time at one-second intervals in decimal form.[†] TUASON said that 1000 was really convenient for human unit conversion, but may not be optimal for machines, with SEIDELMANN recalling French Revolutionary time as a decimal standard for humans that was quite unsuccessful. MAIN emphasized that UTC-SLS is intended for human use; it is not intended for computer convenience. Computer convenience is best served by not having a leap at all. TUASON thought the purpose of UTC-SLS was to run UTC on computers and to be transparent to humans. MAIN replied that the purpose of UTC-SLS was to be able to work with a timescale that has leap seconds without getting the time labels that do not fit the sexagesimal system.

[*] http://www.cl.cam.ac.uk/~mgk25/time/utc-sls/
[†] http://www.cl.cam.ac.uk/~mgk25/time/utc-sls/draft-kuhn-leapsecond-00.txt

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