

PANEL DISCUSSION

POST-GPS END-OF-WEEK ROLLOVER AND UPCOMING Y2K

Chairman: Donald H. Mitchell, TrueTime, Inc.

DONALD MITCHELL (TrueTime): Welcome to this afternoon's session. What we have this afternoon is a panel discussion, and we would like to be able to get some interaction going, at least with the first part of the session. What we had envisioned when we planned this session was that there would be a lot of what we call "Week 1024 Rollover" horror stories.

We didn't have very many of those to present, and I've really searched diligently to try to find some. We have a lot of headlines leading up to that: "GPS may have a greater impact than Y2K"; "GPS faces imminent Y2K-type problem"; that's in August instead of the new year. So this goes on and on with headlines leading up to the August rollover. But we didn't have the anticipated problems that everyone had assumed that we would have. Even the receivers that did not get the updates seemed to come through without any real glitches. I think a big part of the glitches were due to the test phase leading up to the Week 1024.

I'd like to give Steven Hutsell from USNO at Colorado a chance to reiterate some of the things that he talked about in his paper this morning, just in case you didn't hear those things that Steven was talking about.

STEVEN HUTSELL (USNO AMC): Thanks, Don. Like you mentioned, some of the problems that I covered in my presentation kind of broke up into: (1) the problems that occurred during the testing of rollovers; and (2) the problems during the GPS week rollover. The ones that occurred during the testing, though, weren't so much associated with the rollover itself, but just the fact that coincidentally, in order to conduct the testing, 2SOPS had to set vehicles unhealthy. And how users were reading or not reading the health bits in the navigation message dictated how many problems they had during these tests. It's probably the combination of the fact that the satellites were set unhealthy and the rollover testing which was occurring that created the problems for them. Had they been checking the health, they wouldn't have experienced many of those problems.

However, during the actual GPS week rollover, just to recap what I mentioned this morning, there were user sets that mispropagated the TOT or misidentified the correct modulo of the TOT as well as the TOA. And for time-transfer users, mispropagation of TOT can mean, as I mentioned earlier, tens of microseconds of error or more. I think, in fact, they probably got really lucky this time because the A-1 term in subframe 4, page 18 was relatively small. For TOA, obviously, that meant that they couldn't lock up on satellites because they didn't know where they were and they didn't know which ones to look for.

The other problems were ones that we could reasonably expect for any system that wasn't doing any kind of compensation whatsoever for the modulo rollover. And that centered around users, or user sets, not recognizing the ambiguity, losing lock; and some of them requiring resetting or some of them resetting on their own, fortunately. And, as I mentioned, some users chose to disconnect their systems in the interest of integrity or the interest of maintaining their confidence in the system they had and free-wheeling on whatever frequency standards they

were using. And, of course, there were some minor problems with anyone who was working with manual tracking schedules. There are receivers that don't recognize anything but dates between 1980 and 1999. I don't think I saw any catastrophic destruction of any DoD system, but definitely a lot of inconveniences for a lot of people. It would be nice to say that thankfully it's over with, but of course a little bit less than 19.7 years from now it will be coming up again.

MITCHELL: Thanks, Steve. On the beneficial side of the Week 1024 Rollover, of course, is the Y2K issue. Because of the manufacturers' diligence in the timing community to make sure that we did the 1024 Rollover without any inconvenience to the system users, Y2K became a big part of that. So in the testing phase of testing the GPS receivers with simulators for the 1024 Rollover, of course all the manufacturers, I'm sure, tested Y2K issues along with that. So hopefully we will not have any real Y2K issues, and I don't know if we'll have a panel like this next year looking at Y2K horror stories. But I don't suspect that we're going to have many Y2K problems with the GPS timing community. Maybe with the instruments that are tied to our timing receivers, but not the receivers themselves.

We do have another issue, and we have Dennis McCarthy here to discuss that. And this is UTC. So at this point, I would like to turn this over for Dennis's discussion on UTC. After that, we'll have a few minutes for questions and answers.

DENNIS McCARTHY (USNO): Okay, I wondered if maybe this was the right forum to bring this up. But the issue of leap seconds and the very definition of UTC is one that keeps coming up and one that I think is kind of suited to a panel discussion of sorts. And, hopefully, maybe we can get some feedback, some concerns, and some interest — and even some ideas — on that.

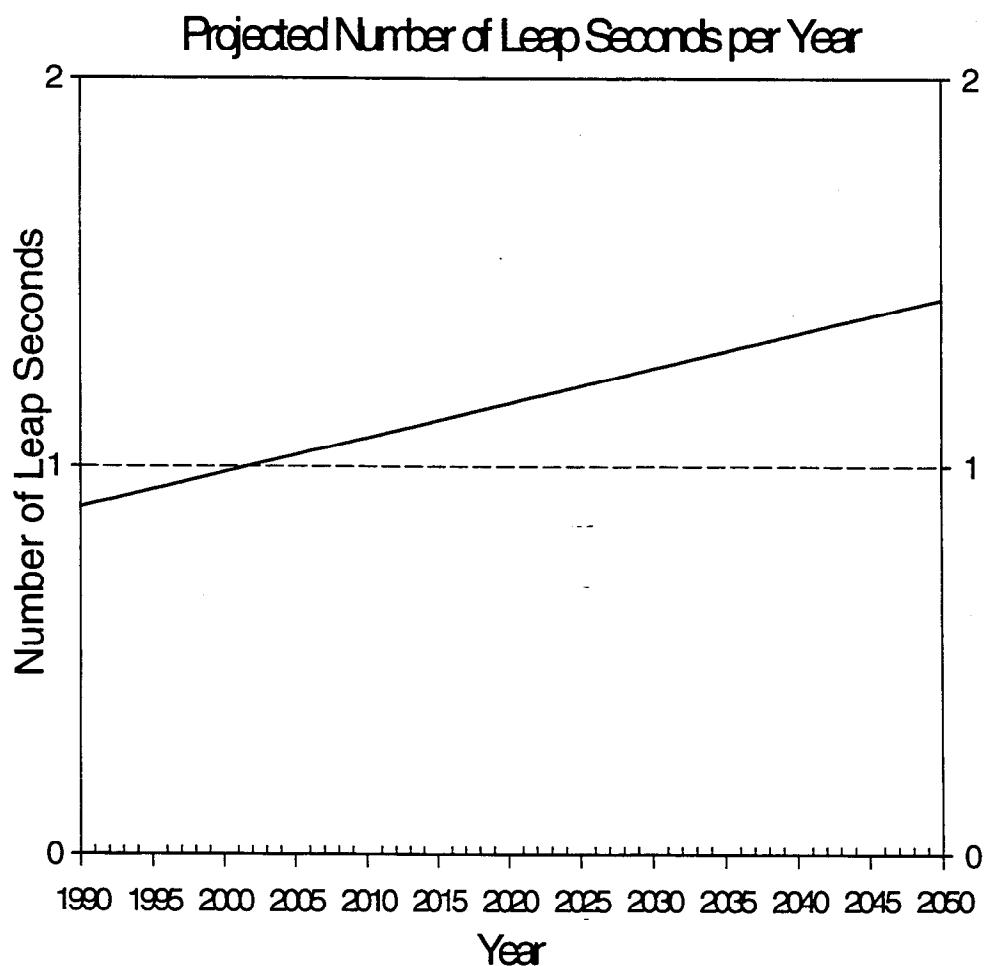
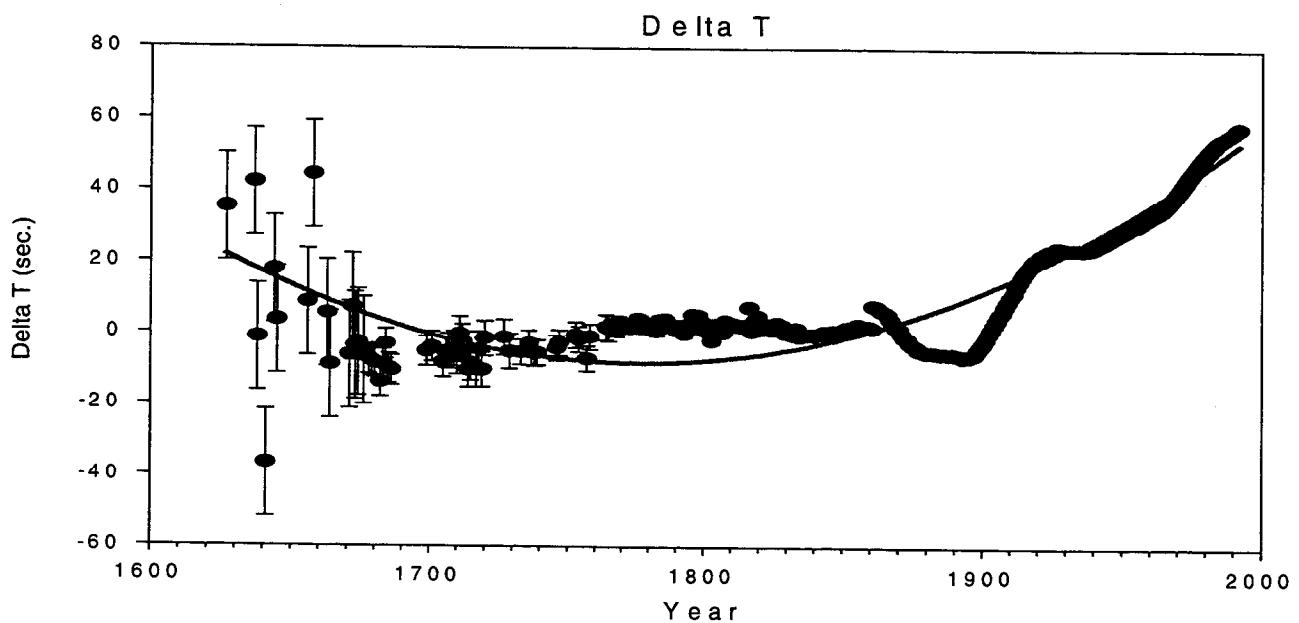
I've been asked here a number of times just what is this issue and what is this problem of the leap seconds and what are we concerned about. And so here are some viewgraphs which I hope kind of illuminate the issue and make it clear as to what we're talking about.

Basically, this viewgraph is the history of the SI second; it's a familiar definition. But the SI second is actually defined in terms of the ephemeris second. And that ephemeris second is based on the fraction of the tropical year in 1900. And the tropical year in 1900 is defined using astronomical observations which were actually made in the 19th century. So this very definition of the second is equivalent to the astronomical second defined by the rotation of the earth in the middle of the 19th century; this was all done in the 1800s. And, of course, UTC was introduced in 1972, so that the difference between the astronomical time and the UTC second has to be less than 0.9 second, and that's why we introduced leap seconds.

Well, unfortunately, the earth is being decelerated by the tides. That will continue. It has been doing that for eons; we have astronomical observations that date back at least a few thousand years which are based on eclipses. This viewgraph illustrates the ΔT observations made since we began to use telescopes, but if we were to continue this back 2,000 years, we would see that this parabola that's defined here just keeps right on going and approaches minutes in length.

So, yes indeed, we are now here and this parabola will continue to go up. And so what that means for the user is that we will continue to have leap seconds. And not only that, we will have leap seconds at a growing rate. We will continue to have a leap second probably about once a year, and probably within the next 50 years it would not be unusual at all to have 2 leap seconds per year being inserted.

There are wiggles on that curve, as you see; that's why we can't predict it. It's basically unpredictable because there are decadal-type fluctuations in the earth's rotation rate, so we just can't build this into UT1 minus UTC.



So the causes for concern are that the frequency of the leap seconds is increasing and that will be an increasing public annoyance. Every time we do one of these things, we always have some consternation on the part of the public about why we put this leap second in, why it must be so often, and can't we do something about it. So that's one issue.

Communications problems: networks that have to go down for some short period of time in order to resynch because they don't all put in the leap second at exactly the same time. That's become an issue. And because of that, there has been a growth of systems which are, in a sense, instituting their own time so that they don't have to bother with leap seconds. So that we're going away from UTC or TAI or any of these things because they just don't want to bother with this; they'll create their own time scale. GPS is, in fact, one, but there are others.

So in the interest of raising some discussion, there is an article in the latest issue of *GPS World* which sort of illuminates this and brings forward a lot of these issues. But here are the options. There may be other options which maybe some people would like to bring forward. First of all, we can do nothing; we can discontinue the leap seconds; we can redefine the second; we could increase this tolerance for UTC minus UT1; it's 0.9 second right now. Maybe we could do something about changing that. Or we could do something else about making this adjustment, how these are lumped into periodic adjustments of UTC. Maybe we can make an adjustment once every 10 years, or 5 years, or something like that where we would just catch UTC up with what the astronomical time is telling us. Or maybe we should just wait until we reach some magic time where it amounts of a minute or something like that.

Well, to give you an idea, if we were to keep the status quo going, the number of leap seconds, if I just base this on that parabola that I showed you earlier, we can see that we should at least have, by the year 2000 or a little past 2000, a leap second almost every year for sure. In 50 years, about one and a half leap seconds you can count on each year, which means that some years will have two. So that's what will happen if we continue.

If we were to discontinue leap seconds all together, it would look like this. Here we are now. If we look at the UTC minus UT1 as a function of the recent time, we can see we've been down here keeping within our 0.9-second limit quite nicely. But if we were to suddenly disregard that, the difference would go something like this; and you can see that in about a hundred years, we would have accumulated about 2 minutes worth of difference between UTC and UT1. So, that's the size of the problem. It's a 2-minute problem.

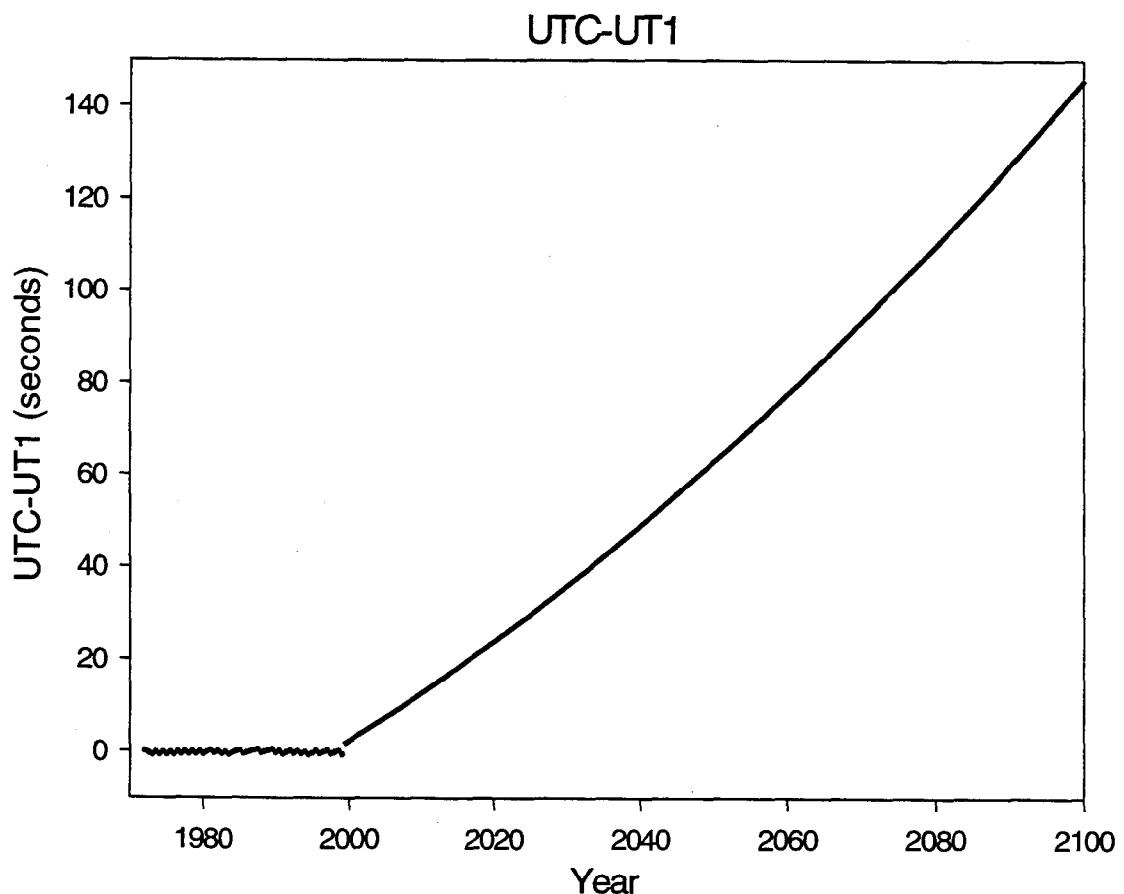
Well, we could redefine the second. That raises all sorts of issues and it's probably the least desirable. And although I've said it's sort of a fundamental solution, it's not really fundamental, because we would have to keep correcting the second if we were to keep up with the rotation of the earth and deceleration. The fact is, you know, it is an acceleration and when you integrate that twice we have this problem where we have to keep correcting the length of the second.

This is the size of the correction — I've shown it here — that would be needed in the nine-billion cycles per second definition of the length of the second, defined in terms of cesium. The point of this that this is something that we would have to continue to do at some point. Also, the arguments against it are that it would require redefinition of physical units, other things which are defined in terms of time.

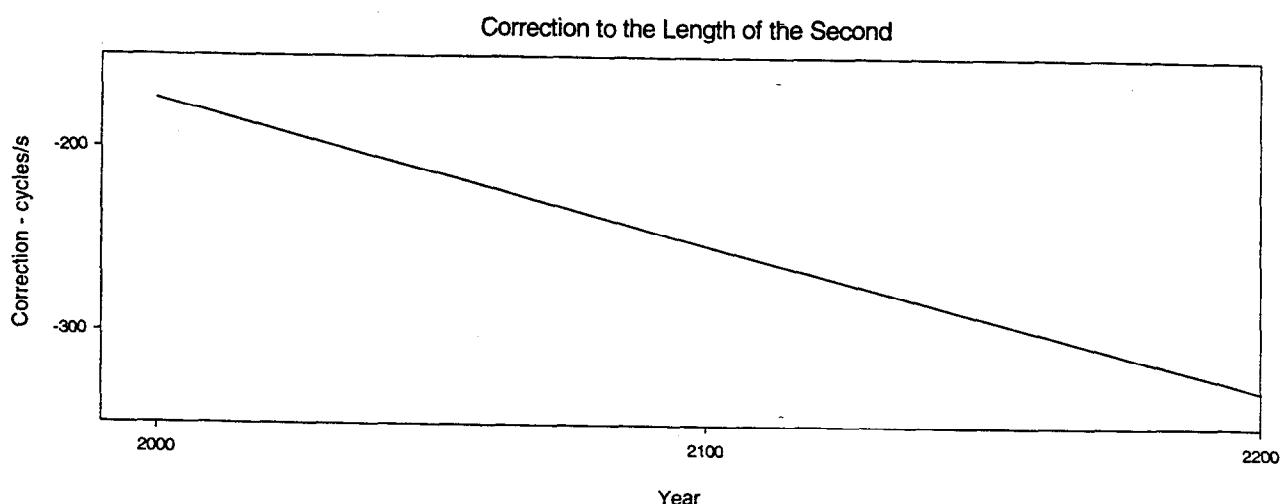
Increasing the tolerance: well, it's easy to do and we could do it rather quickly even. But this would make for larger discontinuities; the date of adjustment would be unpredictable, so it would be difficult to establish some acceptable limit which everybody is happy with.

And then there is the periodic adjustment of UTC where at least we would make the date of adjustment rather predictable so we would know ahead of time that it would be done every 10

Discontinue Leap Seconds



Redefine the Second



years or 5 years or whatever. But we wouldn't necessarily know how many of those seconds we were going to insert and it would make for large discontinuities.

So those are the issues. I should point out that this topic has been raised in other venues. It was brought to the attention of the CCTF earlier this year, and recommendation was made that for those people who want to use a timescale which does not have these leap seconds in it, there is always TAI. And you can make perfect use of TAI. The difficulty with that is, of course, that it's not very accessible in the sense that UTC is accessible. It has become an official question for the ITU-R to study and so presumably will elicit comments and some recommendation in the future, hopefully. And the question was raised at the recent URSI meeting, and URSI has formed a working group.

And probably everyone in this room has been bombarded at least once with the questionnaire that Demetrios Matsakis has sent around asking for opinions on that. I must say that the opinions – if I could summarize, and maybe Demetrios can correct me on it – are mostly along the lines of "Well, it probably wouldn't make too much difference to my system, but please don't do it because it just makes life too difficult for me, and I'd like to continue whatever it is that I'm doing." For those who are opposed to it, the arguments are that they are making use of the fact that UT1 at the second level can be considered to be equal to UTC. So if you are only interested in second-style accuracy, UT1 is UTC now, and you don't have to worry about what is the difference between UT1 minus UTC; you can just ignore that fact and continue on. If you've made any changes, then you might possibly have to take into account that there is a difference; and you would have to rewrite code and rewriting code is very expensive, and you don't want to spend the money on it.

And yet another argument against doing anything is that there are formats out there which allow for the fact that the difference between UT1 minus UTC is less than a second; it's less than 0.9 second officially. So if there were any changes made, then we would have to allow for a change in the format of some number someplace, and one doesn't have space in one's format to do that. So please don't make changes because of that.

So these are the arguments and the issues in a few words. And hopefully we can argue about it.

Questions and Answers

DAVID ALLAN (Allan's Time): I am very happy to see you bring this on the floor here at PTI, an appropriate place in my opinion. It's interesting to me that, as you look at the equation of time, you see plus or minus something in the order of 15/16 minutes over the course of the year, and nobody pays attention to that. The sun moves back and forth and it's not a bother. And I think we get locked up with positions; I think it's really important for us to examine long-term benefits to society of making rational, meaningful decisions. So I'm very happy to see it on the floor and open for discussion.

I think there are some very good ways to go. One simple suggestion would be to do it once per century. That still would be much less than the equation of time.

DENNIS McCARTHY (USNO): The other argument is also that we have Daylight Saving Time where we change things by an hour, and that doesn't seem to make too much of a problem.

PETER WOLF (BIPM): Could you just specify in what respect you think that TAI is less accessible than UTC? I think if you have UTC and you know the offset between the two, which is an integer number of seconds obviously, then the two are equally accessible, at least for the scientific user; and many people do indeed use TAI already.

McCARTHY: I'm just saying that it's less accessible because we don't have clocks on the wall which keep TAI.

WOLF: So you mean basically the fact that most legal times are defined in terms of UTC rather than TAI?

McCARTHY: Precisely. That's it. It's just not something that the non-expert in the field is even aware of.

WOLF: But then again, most people that are really bothered by the leap second like, say for example, navigation systems that have their own time or want the timescale that does have leap seconds, in a sense couldn't they be independent of legal time? They have their own timescales already, so I don't think they care much about legal time in any sense. So why couldn't they use TAI?

McCARTHY: Well, I think that a possible solution is to use TAI. But if we were to use TAI, then I think we should make more of an effort to make it known more widely and make it more accessible to sort of that user who lies in-between that area of people who care and people who don't care.

JUDAH LEVINE (NIST): There already is an awkwardness about time tagging events that happen during a leap second, because the official definition of a leap second uses the nomenclature "60" for the second name. But if you keep time in terms of binary numbers or any other non-ASCII string system, then there is no natural way of naming a leap second. And all of us cope with that by kind of holding our breath during a leap second and basically not naming anything that happens in that second.

Now, if you were to make the leap second correction less frequent so that you had more of them, then that interval during which we have to hold our breath gets longer. Because there are now a whole bunch of leap seconds, and we need a way of naming them. Because if you did it every century and there was a whole minute that was not well specified in the normal

formats, it would create an enormous hassle for computer folk.

McCARTHY: That's true.