National Legal Requirements for Coordinating with Universal Time[*]

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The abolition of intercalary (leap) seconds within Coordinated Universal Time (UTC) would create a new civil time standard fundamentally different from solar time. Having no known civil precedent, such a standard would present national governments with certain legal, technical and philosophical questions brought by the abandonment of the long-standing solar-time standard. This paper attempts to raise awareness of some of these questions; specifically, the laws of several nations and the European Union now require time based on the mean solar time at the meridian of Greenwich, or, if one prefers, Universal time (UT). Since there is no legal requirement for ultra-precise uniformity of rate for civil time based on Greenwich mean time, the continued synchronization of atomic UTC with Universal time has allowed UTC to proliferate as a legally acceptable world standard. It is presumable that some nations elevated the legal status of "UTC" in the belief that a time scale named "Coordinated Universal Time" would remain coordinated with Universal time in perpetuity. For this reason, a civil broadcast standard no longer coordinated with UT may not be easily reconciled with existing national statutes, regardless of its name. Therefore, civil broadcast standards failing to approximate Universal time may best forego use of the label "Coordinated Universal Time" and its acronym "UTC", since these descriptions have always implied a realization of Universal time, in title and purpose, within and without the law.

INTRODUCTION

Coordinated Universal Time (UTC) is a time scale maintained by the *Bureau International des Poids et Mesures* (BIPM) with assistance from the International Earth Rotation Service (IERS).[†] It establishes a base for the coordinated distribution of standard frequencies and timing signals per ITU-R Recommendation 460.[1] UTC has the same rate as International Atomic Time (TAI) maintained by the BIPM, but UTC is adjusted relative to TAI by inserting (positive) or neglecting (negative) intercalary ("leap") seconds to assure its rough concordance with Universal time. UTC therefore differs from TAI by an integral number of seconds.

There are two concepts that define the duration of time known as the second. Universal time (UT) is a precise astronomical measure of the rotation of the Earth on its axis,

[*] These comments are solely attributable to their authors and do not present an official view of the United States.

[†] The IERS recently elected to rename itself the International Earth Rotation and Reference Systems Service (*Service International de la Rotation de la Terre et des Systèmes de Référence*), pending approval of its sanctioning bodies.

synonymous with mean solar time at the meridian of Greenwich, also known as Greenwich mean time (GMT).[2,3] The mean astronomical second is $^1/_{86400}$ of the mean solar day.[4] The more recent *Système International d'Unités* (SI) second is based on 9192631770 periods of the radiation emitted from cesium 133 at a temperature of 0 K.[5] This atomic second was calibrated against the theoretically uniform "Ephemeris time"—the pre-relativistic independent variable of solar system ephemerides based on astronomical observations from the 18th and 19th centuries.[6] Astronomical time serves as the basis for civil time, but Ephemeris time was never intended or designed to represent mean solar time exactly.[7,8] Some kind of adjustment is then needed if civil time (based on Earth rotation) is also expressed in terms of SI seconds (based on Ephemeris time).[9]

UTC is an elegantly devised, continuous* time scale having duality of purpose: it completely preserves the ultra-precise uniformity of atomic rate while maintaining close proximity to Universal time. Specifically, it has always respected national statutory requirements for Greenwich mean (solar) time better than one second. The *Conférence Générale des Poids et Mesures* (CGPM) endorsed the usefulness of UTC as a basis of civil time only after "considering that […] UTC is […] an approximation to Universal time, (or, if one prefers, mean solar time)."[10] Prior to CGPM endorsement, few (if any) countries had adopted UTC as a true legal standard. Almost all countries now acknowledging UTC adhered to a UT standard prior, and recognized UTC as a realization of Universal time in title and purpose at the time of legal adoption. Consequently, a requirement for mean solar time is reflected in all time-keeping law today; legal time is referenced to Earth rotation in some countries, in others it is based on atomic time adjusted for Earth rotation, but in no country is legal time known to disregard Earth rotation.

The International Telecommunication Union Radiocommuncation Bureau (ITU-R) has recently assumed international responsibility for the definition of UTC by forming a Special Rapporteur Group (SRG) to report to the ITU-R with recommendations regarding possible changes to the current procedure relating UTC to TAI. At its second meeting in Paris, 21-22 March 2002, the SRG converged to the opinion of freezing the difference between UTC and TAI at the current value of 32 seconds.[11] It further decided that it would be necessary to retain the name "Coordinated Universal Time" and the abbreviation "UTC" to avoid potential problems regarding the definition of national time scales in countries where UTC is the legal basis; otherwise, many laws might have to be

* The practice of coercing generic "UT clocks" to display UTC results in unfortunate mischaracterization of the atomic UTC time scale. One is that UTC lacks sequence or coherence (*e.g.*, is "discontinuous"), when in fact, UTC is completely sequential and coherent within the prescriptions of the UTC standard.

rewritten to account for this change. Unfortunately, it is very difficult to contrast the existing UTC standard with the SRG's unofficial consensus recommendation without giving that recommended standard a different name. In this paper, the proposal shall be referred to as *Uncoordinated Universal Time* (UTNC, *Temps universel non coordonné*).

The practical effect of proposed UTNC is to change the basis of civil time-keeping from solar time and/or Earth rotation, which may not be legal. Certainly nations that recognize Universal time or "Greenwich mean (solar) time" as an explicit legal standard (United Kingdom, United States, provincial Canada,[12,13] provincial Australia,[14] Ireland,[15] *etc*.) cannot be spared from addressing the legality of a fundamentally new civil standard like UTNC. For nations that legally recognize "UTC" (France, Germany, the Netherlands, Switzerland, *etc*.), a valid legal question might be whether the meaning of the time scale entitled "Coordinated Universal Time," once legally adopted can, of right, be changed without national legislative endorsements through statute. Legal and technical considerations may then necessitate a uniquely different name for such a fundamentally different standard.

"WHAT TIME IS 'IT'?"

Civil Time

The ultimate nature of time is a deep and uncertain philosophical question.[16] In the 15th century, Leonardo da Vinci noted that time-keeping involved concepts of position and extension (duration), the former responding to the question of "When?" while the latter responding to the question of "How long?"[17] When atomic time scales became available philosophical arguments flourished about the fundamental distinction between the astronomical measurement of "time" versus the atomic measurement of "time interval." One argument for having civil atomic time closely coordinated with Universal time was that atomic resonators, being ultra-precise frequency generators, only provided for a measure of "time interval" from an arbitrary epoch but not a measure of "time" in the most fundamentally understood sense.[18] This appears to be one of the motivating reasons for the UTC time scale as it exists today and, arguably, why it has served acceptably well as a legal standard internationally.

Another motive for the current definition was its historical continuity with solar time-keeping going back to antiquity. Historically, civil time has been recorded by recurring astronomical phenomena, these being moderately verifiable by the general public. According to Newcomb (1906), a distinction between "day" and "time of day" has resulted in two divisions for time expression:[19]

> The main purpose of a measure of time is to define with precision the moment of a phenomenon. The methods of expressing a moment of time fall under two divisions: one

> relating to what in ordinary language is called the "time of day," and depending on the earth's rotation on its axis; the other on the count of days, which leads us to the use of years or centuries. In any case, the foundation of the system is the earth's rotation. The time of this rotation we are obliged, in all ordinary cases, to treat as invariable, for the reason that its change, if any, is so minute that no means are available for determining it with precision and certainty. [*sic*] There are theoretical reasons for believing that the speed of rotation is slowly diminishing from age to age, and observations of the moon make it probable there are minute changes from one century to another. If such is the case the retardation is so minute that the change in the length of any one day cannot amount to a thousandth of a second. Yet, by the accumulation of a change even smaller than this through an entire century, the total deviation may rise to a few seconds and, in the course of many centuries, to minutes.

Of Newcomb's two divisions for time expression, recurring "time of day" appears to be less fundamental because it is defined by, or expressed as a function of, the "day" itself. Newcomb's basic understanding of time is interesting in another respect: the gradual lengthening of the (mean solar) day was already known, even before it was widely adopted as a statutory basis for legal and civil times. The astronomical basis for time applies not just to the time of day but also to many civil and religious calendars (which have been incrementally corrected, rather than abandoned, despite their own long-term imperfections).

While mean solar time had been used for centuries, the introduction of Newcomb's fictitious Mean Sun enhanced the practicality of this standard. Explicit almanac references to the Mean Sun were used until the official implementation of Ephemeris time in 1960.[20] Today, Universal time is not explicitly based on an analytical Mean Sun, but defined to be linearly proportional to Earth rotation angle.[21] By so doing, modern-day Universal time must deviate secularly from solar time, although the divergence has been made so extremely small that "Universal time" and "mean solar time" remain practically equivalent in the very long-term.[22]

Time-keeping nomenclature is often confusing in the general literature. For example, the Macmillan Encyclopedia vaguely defines Greenwich mean time as

> the local time at Greenwich, London, located on the 0° meridian, from which the standard times of different areas of the globe are calculated, 15° longitude representing one hour in time. In 1986, it was succeeded by coordinated universal time (UTC).[23]

There appears to be professional confusion over the current legal status of Greenwich mean (solar) time as well, even among those appointed to study the topic. For example, the International Union of Radio Science (URSI) Commission J Working Group on the Leap Second reported that Greenwich mean time "has not existed for thirty years" legally.[24]

Question ITU-R 236/7 "The Future of the UTC Timescale" (2000),[25] after considering

> that UTC is the legal basis for time-keeping for most countries in the world, and *de-facto* is the time scale used in most others;

decided that the following should be studied:

> What are the requirements for globally accepted time scales for use in both navigation /telecommunication systems, and for civil time-keeping?
>
> What are present and future requirements for the tolerance limit between UTC and UT1?

Civil time-keeping is, arguably, time kept for common "everyday" purposes, whatever they may be, in order to satisfy the needs and expectations of the general public. Unfortunately, this level of definition is impracticably vague. As implied by the Question, civil time requires "legal" context for precise definition and assessment of "present and future requirements."

Legal and Regulatory Time

The word "legal" means of or relating to law, where "law" implies imposition by a sovereign authority and obligation of obedience by all subject to that authority.[26] The issues of imposition and obligation become complicated when internationally recommended practice conflicts with national legality. Furthermore, there are various classes of national law: *statute law* is that prescribed by legislatures, *case law* is established by judicial decisions (sometimes owing to an interpretation of ambiguous legal nomenclature or obsolete terminology), and *regulation* deals with details or procedure by one so legally authorized.[27] When statute and regulation conflict, it is often resolved through the issuance of case law or changes in regulation, rather than the revision of statute itself.

Within the context of this discussion, *legal time* is that prescribed by the law or decree of a national sovereign authority within its own jurisdictional boundaries. To be legally viable, the time realized by national regulatory authorities must remain true to the law it intends to reflect, but may still be different than what the law prescribes at some level. Because of this, it may be prudent to give it a different label, such as *regulatory time*. One might then say:

> *Regulatory time* is a realization of a legal time legislated by a sovereign authority in order to satisfy public expectations for civil time based on historical, philosophical, religious, or technological prejudices.

Within the context of Question ITU-R 236/7, "civil time-keeping" presumably refers to legal time enforced and maintained—that is, regulatory time at the national level.

THE NEED TO CONSIDER NATIONAL TIME-KEEPING LAWS

National governments generally maintain their own realizations of UTC for civil and legal use in real time. International treaties serve to establish and harmonize standards insofar as the civilian user communities recognize, and their local governments enforce, those definitions and recommendations through national legislation (where "enforcement" might include the disbursement of public monies for the national maintenance and distribution of so called regulatory time). The Question "What are the requirements… for civil time-keeping?" seemingly urges careful examination of national statutes establishing time standards for individual governments.

This viewpoint may not be shared by all. For example, Nelson *et alii* (2001) imply that the laws of individual nations may be either irrelevant to UTC redefinition, or only relevant after UTC has been redefined (rather than before).[28] The rationale may be that few national laws numerically stipulate the required proximity between regulatory time and astronomically based legal concepts like mean solar time or Universal time.[29] Since summer-time (or, daylight-saving-time) legislation causes discontinuities as large as one hour in national civil times, it might be argued that nations would acceptably substitute UTC's leap seconds with "leap hours" without any required changes to existing legislation.

However, national standards for time are made up of two separate and distinct legal concepts. One is civil time itself, as indicated by one's local clock; the other is the background or basis time to which these civil clocks are referenced. Some (but not all) statutory time scales allow for large summer-time discontinuities of the local civil clock, but no nation is yet known to express legal tolerance for any significant adjustments to the *basis time* which regulates civil standards.

Any small problems now associated with leap seconds would be amplified with leap hours, when they eventually occur. However, the need for a leap-hour adjustment would likely not occur for another six to eight centuries, and it may be unreasonable to assume that posterity would honor (or perhaps even know about) such proposed adjustments.[30] For these reasons, the leap-hour proposal relinquishes the long-standing mean solar day, supplanting it with a "metric" day of exactly 794243384928000 cycles of cesium-133 radiation, or 86400 SI seconds.[31] Technically, "day" and "year" are non-SI units and the legality of an "atomic calendar" is unclear. Hence, thorough consideration of national laws is necessary to ensure that internationally broadcast time standards remain acceptably legal.

LEGAL REQUIREMENTS FOR MAINTAINING UNIVERSAL TIME

Civil time-keeping law still reflects the expectation that Earth rotation relative to the Sun regulates the civil notion of Time (including the meanings of commonly understood concepts and words such as “day”, *etc*.). There can be little doubt that there is a true legal requirement for solar time, made explicit through the introduction of civil time zones globally, the sole purpose of which is to correlate the passage of the Sun along a standard meridian at civil noon. While the accuracy of civilian timepieces has greatly improved to a point where a leap second might be detectable, very few timepieces support (display) leap seconds. Arguably, clocks of such manufacture are still generic Universal-time clocks. Such anecdotal evidence might further imply that generic Universal time, rather than UTC, is the standard being upheld, employed, or expected by the general public.

Legal Use of Universal Time

Today, statutory standards for time are expressed and/or understood in navigational or astronomical terms (*e.g.*, “longitude”, “meridian”, “Greenwich”, *etc*.), and even time legislation explicitly based on “UTC” usually has some navigational basis (time zones, *etc*.) The navigational use of “Greenwich mean time” implies UT1, yet the uniformity of UT2 also made it the basis for standard-time broadcasts for many years.[32] However, the original (legal) concept for mean solar time generally predates the various realizations of Universal time now in use (UT0, UT1, UT2, and UTC). Universal time is also something to be observed and extrapolated, or reduced after the fact, and different people may acceptably observe and reduce Universal time differently (the methods of which are also unspecified under law). This further implies that the law has never placed extremely rigid statutory prescriptions on the realization of legal UT.

For these reasons, one cannot definitively assign a specific realization of UT within most legal contexts. This may also be why UTC (as a realization of UT) has endured as a legally acceptable proxy for Universal time. Certainly, the unchallenged juxtaposition of UTC for “mean solar time” in many applications suggests that one second may already be a legally allowable level for civil-time ambiguity.

Standard Time of the United States

Statutory authority over standard time in the United States resides with its Congress. When the US Congress first enacted the Standard Time Act of 1918, it legislated “That, for the purpose of establishing the standard time of the United States, [...t]he standard time [...] shall be based on the mean astronomical time of [...] longitude west from Greenwich.”[33] At this time there were only two concepts that could be interpreted as “mean astronomical” time: sidereal time and solar time. Both were defined by Earth

rotation, each rate proportional to the other, and it was already thought that the length of the mean solar day was increasing at a rate of many seconds per century.[19] Newcomb had suggested that "astronomical mean time" technically described the day starting at noon, yet within the historical context of long-standing civil conventions, the phrase "mean astronomical time" was all that Congress needed to convey a precise legal notion of the mean solar day beginning at midnight on the meridian of Greenwich, as recommended by the International Meridian Conference of 1884.[34] Since the difference of twelve hours between civil and astronomical time was apparent as night and day, there was little concern over the need for more specialized legal nomenclature, even though this concern ultimately resulted in the recommended use of the term "Universal time" in place of the term "Greenwich mean time" by the International Astronomical Union (IAU).[35]

By 1958 however, the IAU had defined a more uniform astronomical time scale known as Ephemeris time, the rate of which was adopted by the CGPM in 1960 to define an SI second.[36,37] The appearance of another uniform, yet fundamentally different, astronomical time scale approximately one-half minute from mean solar time rendered the previous legal descriptor "mean astronomical time" ambiguous. Subsequently, Congress passed the Uniform Time Act of 1966 with language clarifying that standard time would continue to be regulated by the astronomical concept of Universal time rather than the astronomical concept of Ephemeris time.[38] Congress did so by replacing the phrase "mean astronomical time" with "mean solar time."

Such Congressional action may be historically and legally important, as it afforded unambiguous legal protection for mean solar time when a more uniform (but secularly deviating) time scale was available and might have been interchanged owing to the obsolete wording of law, not unlike the recent UTNC proposal. In hindsight, this action may also suggest a low legal tolerance for a basic time standard differing more than several seconds from what was legally intended or required. But perhaps just as important, the distinctions in the realization of broadcast Universal time (*i.e.*, UT2), and even the more astronomically precise term "Universal time" itself, went unrecognized under the Uniform Time Act. This further suggested that Congress was not only tolerant of subtle ambiguities in the realization and legal meaning of "mean solar time" (all being well below one second), but desired to emphasize the conceptual aspect of "solar" time in an astronomical standard.

Although Congress has left US-standard time defined in astronomical and navigational terms to this day, addenda to federal code have recently acknowledged UTC as an acceptable proxy for mean solar time where limited to most practical purposes associated with radio regulations and telecommunication.[39] "UTC" in this context still refers to an

atomic time scale that remains within 0.9 seconds of Earth rotation, per the Federal Radionavigation Plan (an official US policy published jointly by the US Departments of Transportation* and Defense).[40] But as a legal basis for regulating civil time, US code is not known to have otherwise acknowledged or supported the use of Ephemeris time, or any "uncoordinated" variants of its successor TAI. Instead, US code legally authorizes the use of the SI second as a measure of time interval as part of the metric system.[41] Mean solar time measured in SI seconds then appears to be legal in the US. This, of course, describes UTC as it is currently defined.

Standard Time of the United Kingdom

When Greenwich mean time became a legal standard across the UK in 1880, there was no other civil meaning associated with GMT beyond mean solar time at Greenwich.[42] Today, one confusing aspect is that some civilian applications casually use "GMT" to describe UTC. Furthermore, Parliamentary law never specified a legal name for British Summer time (which is GMT plus one hour); this too results in occasionally incorrect descriptions of British Summer time as GMT. That Greenwich mean time has come to be recognized as being synonymous with UTC in ordinary language does not further imply that these two concepts are permissibly interchanged within the law (particularly should UTC be redefined as something uncoordinated with Greenwich mean time). No known discovery of British (statute or case) law equates the astronomical concept of Greenwich mean time with atomic UTC, or otherwise legally redefines the phrase "Greenwich mean time" beyond its original astronomical definition.

Interestingly, it is the presence of leap seconds that makes Greenwich mean time largely synonymous with UTC, and justifies the practical use of UTC as a proxy for GMT where GMT is prescribed. In 1978, Donald Sadler commented that "the two forms of [atomic and solar] time-scale are fundamentally different; both are essential […] and it would seem important to ensure that no unnecessary confusion between them is introduced."[43] Yet in those countries where UTC was not made explicitly legal, one can conclude that Earth rotation, and not atomic time, was intended as the ultimate basis for civil time. This intention has been most explicit within the UK, where bills attempting to replace GMT with UTC have been recently debated but failed to overcome Government neutrality.[44,45]

Standard Time of the European Union

The directives of European Parliament reconciling the application of summer time (or, daylight saving time) across the European Union also prescribe Greenwich mean time or

* The responsibility for standard time and time zones in the USA resides with the Secretary of Transportation, per US Code Title 15, Chapter 6, Subchapter IX, Sec. 262.

Universal time as the legal basis for EU-standard time.[46] This legislation applies to EU member countries that otherwise hold UTC as a national legal basis for time.

Because many English-speaking countries legally recognize GMT, yet many non-English speaking countries now recognize UTC, an interesting question is whether "Greenwich mean time" simply occurs as an English language substitution for UTC in EU parliamentary law. However, it does appear that most original language variants of EU parliamentary act also specify Greenwich or Universal time, rather than UTC explicitly.[*] Also, English speaking countries make the legal distinction between UTC and GMT as necessary; for example, New Zealand amended its Time Act of 1974 effective 30 March 1987 to henceforth reference UTC in place of GMT.[47] Therefore, legal consistency between member countries of the European Union will likely require very close coordination of Coordinated Universal Time and Greenwich mean time.

Historic Universal Time (GMT) in France

Prior to its complete legal adoption of UTC on August 9, 1978,[48] France had decreed its legal standard for Greenwich mean time as "Paris mean time, retarded by 9 minutes and 21 seconds."[49] The earlier decree specified a legally recognized level of precision of one second for GMT or Universal time. By design, UTC has never deviated from France's originally designated legal resolution for Universal time; France thereby adopted a UTC time scale historically compatible with, if not identical to, Universal time as previously acknowledged under French law.

There are two types of solar time, mean and apparent, which are unbiased with each other and differ +/-15 minutes annually. It has been suggested that civil authorities are likely to be tolerant of large offsets in | UT - UTNC | insofar as they remain at levels near the difference of mean and apparent solar times.[50] However, it is noteworthy that the static difference between Paris and Greenwich local time is smaller than the periodic difference between mean and apparent solar time, and *much* smaller than the eventual static offset implied by "leap hours." Paris and Greenwich time differed to such a degree that France found it necessary to legally account for the difference, establishing another precedent for legal intolerance of standard-time differences beyond one second of what was intended or required.

Legal Time of All Countries

With the advent and proliferation of mechanical time pieces, civil conventions for uniform time became, almost exclusively, expressed as mean solar time. Even after

[*] English translations suggest "universal time" (French, Portuguese, Italian, Spanish), "world time" (German, Dutch), "Greenwich mean time, GMT" (English, Finnish), and "(UTC)" (Danish).

uniform atomic time became available as a broadcast standard, its civil and legal acceptability was only secured through leap-second adjustments for the sole purpose of emulating the mean-solar-time standard. Currently, no nation is known to recognize a legal basis for time uncoordinated with Universal time, and it is reasonable to presume that some—perhaps most—countries originally elevated the legal status of "UTC" with the conviction that a time scale named "Coordinated Universal Time" would remain coordinated with Universal time in perpetuity.

SOME ADDED CONCERNS FOR A PROPOSED "UNCOORDINATED UNIVERSAL TIME"

A Legal Definition for Uncoordinated Universal Time (UTNC)

Even among experts in horology, precision time-scale definitions have not come easy.[51,52] Legally, *Uncoordinated Universal Time* would likely be acknowledged as a time scale equal to International Atomic Time (TAI) plus a static offset. Unfortunately, the formal definition of TAI may be insufficiently terse for legal purposes, owing to the complexity of the subject. In 1971, the CGPM requested the *Comité International des Poids et Mesures* (CIPM) give a definition to International Atomic Time already in use,[53] the tenuous submission of the *Comité Consultatif pour la Définition de la Seconde* (CCDS)[*] having been

> International Atomic Time (TAI) is the time reference coordinate established by the Bureau International de l'Heure[†] on the basis of readings of atomic clocks operating in various establishments in accordance with the definition of the second, the unit of time of the International System of Units.[54]

Later, it became necessary to burden the definition of TAI with General Relativity Theory. By 1980 its definition was reportedly "completed" in this sentence:[55]

> TAI is the coordinate time scale defined in a geocentric reference frame with the SI second as realized on the rotating geoid as the scale unit.[56]

To astronomers understanding that atomic resonators can only define time as an interval relative to some (arbitrary) epoch, this definition was still insufficient. A further clarification was advanced by the IAU in 1991:

> TAI is a realized time scale whose ideal form, neglecting a constant offset of 32.184s, is Terrestrial Time (TT), itself related to the time coordinate of the geocentric reference frame, Geocentric Coordinate Time (TCG) by a constant rate.[57]

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[*] predecessor of the CCTF, *Comité Consultatif du Temps et des Fréquences*

[†] This responsibility is now with the BIPM.

(As far as the authors have been able to discover, this clarification has yet to be recognized by the CGPM.) The IAU resolution implies that the origin of TAI is ideally defined in terms of TCG, although practically speaking, TAI is the realization based on the SI second (accurate to the level of the frequency standards) and TCG is practically realized by an ideal mathematical prescription relative to it. To complicate matters a bit more, the IAU further refined TT in 2000.[58]

Political Concerns

The realization of TAI (or, UTNC) is much more complicated than these definitions indicate.[59] There are, for example, different realizations of TAI determined on a monthly basis as well as after the end of the calendar year. TAI is a "paper clock" determined from the weighted average of many clocks in many countries. Some less accurate national clocks are included with minimal weight, mainly for political reasons.

Greenwich mean time overcame many political obstacles which took several decades. Placing atomic UTNC in the foreground may place additional legal, political, or regulatory demands on atomic civil time that background TAI has beneficially avoided. So far TAI continues to be practically defined through BIPM edict, unfettered by national legislation. National law may do well to avoid the subject of UTNC definition, but it may not be able to do so should the basis of Time itself become an open question.

SUMMARY

A new time scale has been proposed equal to "UTC without leap seconds" (UTNC, for *Uncoordinated Universal Time*). This proposal lacks UTC's original duality of purpose and presents governments with certain legal, technical and philosophical questions brought by the abandonment of the long-standing solar-time standard. This paper attempts to raise awareness of some of these questions. While the discussion is not intended to be complete or authoritative, it suffices to illustrate that UTNC may not be easily reconciled with existing national statutes.

In answer to Question ITU-R 236/7 (2000), leap seconds exist because of legal requirements on globally accepted atomic time scales for civil time-keeping. Here, civil time-keeping is that maintained by national regulatory authorities—a realization of legal time expressed by sovereign nations to satisfy public expectations of civil time based on historical, philosophical, religious, or technological prejudices. Astronomical (mean solar) time serves at the basis of the civil calendar and civil time of day. Since this basis is protected legally, citizens are entitled to acquire a reasonably unbiased measure of astronomical time directly from the basis of civil clocks. Thus, users obtaining astronomical time solely from civil clocks drive the present and future requirements for

the tolerance limit between UTC and Universal time. UTC is an atomic realization of UT in title and practice, which is, in turn, the modern-day complement of Greenwich mean (solar) time.

Because atomic time has a rate different than mean solar time, the atomic realization of solar time must be adjusted; for UTC this adjustment is made to the length of the "UTC day," the day being a non-SI base unit. The discrepancy between Universal time and UTC is purposely maintained below one second, a tolerance which appears to satisfy most legal requirements for civil time scales having no significant secular deviation relative to the mean solar day at Greenwich as stipulated under law by most nations (now or historically). Allowable deviations larger than this have no known legal precedent in modern times and do not appear to have been tested or reviewed by national judicial or legislative systems. Legislation endorsing a time scale called "Coordinated Universal Time" that is no longer coordinated with Universal time will remain legally and technically confusing. The potential for legal challenge in national courts is not insignificant given the complexity of national legal systems, even in countries that acknowledge "UTC" by name as a legal standard. Therefore, fundamental changes to the UTC standard would likely require many explicit changes to national laws.

CONCLUDING COMMENTARY

Replacing UTC with UTNC appears unnecessary, as there are other uniform time scales that operate like the newly proposed UTNC, namely TAI and GPS time. It now seems reasonable to ask: what requirement(s) does UTNC satisfy that TAI and/or GPS time cannot; and, if existing UTC unduly promotes the proliferation of independent uniform times, how does the creation of *yet another* uniform time provide an equitable solution?[60] As a realization of UT, UTC satisfies the needs of many scientific, engineering, and technical communities, and removing UTC's leap seconds creates one more atomic time scale less able to satisfy existing and historical requirements for civil time scales based on mean solar time. At this time, there does not appear to be any legal requirement for ultra-precise uniformity in civil time beyond that already being supplied with existing UTC.

Instead, UTNC creates a new question: is a precisely maintained, indefinite sequence of synthetically generated time intervals a sufficiently viable concept to permanently displace humanity's long-standing precepts of what ultimately regulates Time? This question is not related to satisfying the technical conveniences of today's non-standard telecommunication and satellite navigation systems, but is more of a religious, philosophical, or historical question to be thoughtfully upheld by civil law. Such questions were already considered some three decades ago by the International Radio

Consultative Committee (CCIR)[*] and the IAU, and the answer was UTC with its existing system of leap seconds. As currently defined, the existing UTC system is capable of uniquely tagging any event that may possibly occur during the next 1000 years with full atomic accuracy.

For decades, applications with very stringent requirements for timing accuracy (including the Global Positioning System) have continued to operate successfully in the presence of leap seconds. Most applications still non-compliant with UTC came into existence well after the UTC standard was created more than three decades ago. With questions having been raised, national governments may do well to investigate why certain modern-day applications are still either unwilling or unable to comply with international time-keeping standards while others are functionally compliant. National investigations will help discover what, if any, changes to UTC are warranted. This could avoid unnecessary changes to, or tests of, existing (inter)national legislation, and avoid unnecessary burden to systems, applications, and industries already compliant with current standards.

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