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Vocabulary for Time-Scales

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State of Play at ITU-R

- Existing proposal before ITU-R
  - Stop inserting leap seconds in UTC after some date
  - Retain the name UTC
- At RA 2012 the administrations split into 3 roughly equal groups
  - In favour (USA, France, Japan, etc.)
  - Opposed (UK, Russia, China, Germany, Canada, etc.)
  - Need more input
- Pass the issue back to SG7 (WP7A) with a changed mandate
  - Consult a wider range of communities for requirements
  - Consider ALL options to achieve a "continuous" timescale
  - Prepare list of options for WRC 2015

Words are Important

- See the contribution from ISO Technical Committee 37
  - A term is polysemic if, in a particular technical field, it is used for more than one concept (near synonym of pseudonymous)
  - ISO forbids the use of polysemic terms in ISO documentation (including ISO 8601 for the display of UTC dates and times)
- ISO strongly discourages changing the physical significance of the term UTC without also changing the name, which would make it polysemic
- ISO TC37 recommends developing a "concept set" as a first step to resolving the problem

Changes proposed for ITU-R Glossary

- ITU-R TF.686 "Glossary and definitions of time and frequency terms" provides a "concept set" of terms related to time-keeping
- Clarify the issues by modifying the glossary to:
  - Adding new terms to define the structure of time-scales
  - Add terms to describe the distribution of time
  - Redefining existing terms to clarify their proper usage
    - Avoid polysemic terms
    - Provide examples, cross-references, etc.
    - Try to avoid changing their fundamental definitions
- No agreement yet (from anybody!) on the proposed changes
  - All suggestions welcome! (Especially names…)

Questions to address

- Definition of “time-scale”
  - What properties distinguish UTC from TAI?
  - What properties do UTC and TAI have in common?
  - What does it mean to describe a time-scale as “continuous”?
- Distributable time-scales:
  - When we distribute UTC, what is actually being distributed?
  - Is TAI “distributable”?
    - Is TAI conceptually identical to TAI(BIPM)?
    - If we distribute TAI, does that term become polysemic?
  - Should more than one time-scale be distributed?
- How does this affect software specification and development?

Physical Time (modified)

- ***Coordinate time;*** *temps-coordonnée; tiempo-coordenada*
  - *A general relativistic time that approximates absolute Newtonian time for slowly moving observers in an extended region of a particular coordinate system (or frame of reference), so that simultaneous events can consistently be assigned the same value for the coordinate time within a specified accuracy after taking account of the timing consequences of both speed and accelerations (including gravity). Use of a coordinate time simplifies the precise description and scheduling of events in the chosen region. Conceptually, within general relativity a coordinate time has an origin and will be represented by a (mathematical) real number, although an actual clock will approximate this with a specific time coding.*

Physical Time (NEW)

- ***Reference Coordinate Time (RCT):***
  - *A general relativistic coordinate time defined as the proper time generated by clocks embedded on the rotating geoid and propagated to correct for the timing consequences of speeds and accelerations (including gravity) within a given approximation. For practical applications, reference coordinate time is measured by atomic clocks for which the proper time measurement is adjusted to account for the clock's offset from the rotating geoid. Reference coordinate time is conceptually a (mathematical) real number, from a specifiable origin, whose physical unit is the SI second on the rotating geoid; actual clocks will necessarily generate time signals using a particular time code. …*

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Representation of Time (modified)

- ***time code; code horaire; código horario***
  - *A system of digital or analogue symbols used in a specified format to convey time information i.e. date, time of day or time interval. Common forms of time codes include:*
    - *binary, e.g. as a floating point number, or a pair of integers giving a count of seconds and fractions of a second*
    - *character string, e.g. the formats defined by ISO 8601*
    - *date-time structure, decomposing the time into a set of fields representing different units, such as year, month, day, hours minutes, seconds*
    - *rising or falling voltages in a timing circuit*

Representation of Time (NEW)

- ***Date-time conversion algorithm:***
  - *An algorithm that describes how to convert a coordinate time into a date-time structure, which often contains fields for years, months, days, hours, minutes, seconds and fractions thereof. Ideally, a date-time conversion algorithm should be unambiguous, independent of the time at which it is invoked, and bi-directional, such that converting the date-time structure to coordinate time and back returns the same values that were present in the original date-time structure. A generic statement of the algorithm will normally treat the coordinate time as a mathematical real number. The implementation of the algorithm for any particular time signal will, of course, have to accept as input the time code provided by the signal.*

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Representation of Time (MODIFIED)

- ***leap second;*** *seconde intercalaire; segundo intercalar*
  - *An intentional change in the number of seconds per minute, to extend a designated minute by one extra second (a positive leap second) or to finish the minute early by one second (a negative leap second). The leap second is used to adjust coordinated universal time (UTC) to ensure approximate agreement with UT1. …*

RCT	Normal	Positive	Negative
123.0	:57.0	:57.0	:57.0
124.0	:58.0	:58.0	:58.0
125.0	:59.0	:59.0	:00.0
126.0	:00.0	:60.0	:01.0
127.0	:01.0	:00.0	:02.0

Representation of Time

- ***leap second;*** *(cont.)*
  - *NOTE 1 – The "inserted second" or "omitted second" description only applies to time measurements encoded explicitly into years, months, days, hours, minutes and seconds and is to be contrasted with the usual expectation that there will be 60 seconds in every minute as implemented in the uniform date-time conversion algorithm. In a simple decimal or binary count of seconds that correctly represents RCT over decades, no second would ever be omitted, nor would any second appear twice.*

Representation of Time (new)

- ***Uniform date-time conversion algorithm:***
  - *An algorithm that converts a coordinate time to years, months, days, hours, minutes seconds and fractions thereof, assuming there are uniformly 60 seconds per minute, 60 minutes per hour and 24 hours per day, with the count of days being converted to years, months and days according to a standard (e.g. Gregorian) calendar.*
- **Uniform versus "purely atomic" or "continuous"**
  - This document discourages the use of terms like "purely atomic" or "continuous" to describe uniform time-scales. RCT is continuous and measured by atomic clocks; UTC differs from TAI and TI primarily in the date-time conversion algorithm used to convert RCT to a date-time structure.

Representation of Time (new)

- ***UTC date-time conversion algorithm:***
  - *An algorithm that converts reference coordinate time into years, months, days, hours, minutes, seconds and fractions thereof, using 59, 60 or 61 seconds per minute as specified by ITU-R TF.460 and whenever required by IERS, but with 60 minutes per hour, 24 hours per day, and with years, months and days calculated using a standard (e.g. Gregorian) calendar*.
- UTC versus predictability
  - Uniform time-scales are predictable into the indefinite future
  - UTC is not predictable more than a few months into the future
  - UTC has a bounded uncertainty wrt UT1, so better for scheduling Sun-related activities (e.g. celestial navigation, school hours)

MIS-Representation of Time

- Windows and Posix-compliant operating systems and common network protocols like NTP use a **uniform** date-time conversion algorithm in place of the **UTC** date-time conversion algorithm
  - BEWARE: calculated "count of seconds" is NOT RCT
  - Omits positive leap seconds, non-physical negative leap seconds
  - Causes MOST of the operational problems associated with leap seconds

Normal		Positive		Negative	
:58.0	345.0	:58.0	345.0	:58.0	345.0 (346.0?)
:59.0	346.0	:59.0	346.0	:00.0	347.0 (346.0?)
:00.0	347.0	:60.0	omitted	:01.0	348.0
		:00.0	347.0		

Representation of Time (MODIFIED)

- ***Time-scale;*** *échelle de temps; escala de tiempo*
  - *A family of time codes for a particular coordinate time that provide an unambiguous time ordering of events. A time-scale has five main properties:*
    - *the underlying coordinate time*
    - *a particular implementation of the underlying coordinate time by a named clock or time service, having a specifiable uncertainty*
    - *a date-time conversion algorithm (ideally bi-directional)*
    - *a range of time in which the date-time conversion algorithm is well-defined, with a mandatory starting epoch, and (optionally) an ending epoch after which the time-scale may be undefined or ambiguous*
    - *a starting value for the time-scale at the starting epoch*

Representation of Time (new)

- ***Time stamp:***
  - *A time stamp is a digital representation of a time-scale reading that records the instant that an event occurred. Ideally, a time stamp should be unambiguous and permanently valid, i.e. always refers to the same instant in time. Time stamps can be stored for later reference or packaged for transmission.*

Representation of Time

- Binary Time-scales
  - Do NOT break time of day into hours, minutes, seconds, etc.
    - Commonly represent time by real numbers or pairs of integers (e.g. count seconds and fractions thereof from a starting epoch)
  - Used as time stamps for storage and communication
    - NOT intended to be humanly readable
    - Convertible to/from UTC, TAI using date-time conversion algorithms
- Mostly unnamed, and so more difficult to discuss
  - A well-designed standard for binary time-scales that represent RCT could be part of a comprehensive solution
  - BEWARE: JD/MJD represent “days” that vary in length in UTC

Time Distribution (new)

- ***Time signal:***
  - *A time signal is a process that creates and passes time stamps through some medium with a transit delay that can be characterized. Examples include the radio signals used to broadcast UTC, and the protocols used to distribute time over the internet.*
- ***Traceable time signal:***
  - *A traceable time signal has a specifiable uncertainty relative to a reference time-scale. Traceability can be extended along a chain, taking account of the uncertainties introduced during transmission.*
  - *NOTE 1 – Although the time signal is generated in real time, the reference time-scale can be generated after the fact, e.g. UTC.*

Time Distribution (NEW)

- ***Distributable time-scale:***
  - *A distributable time-scale is a specific real-time implementation for creating time signals that are traceable to a source of reference coordinate time.*
  - *Note: UTC is not a distributable time-scale, but UTC(k) usually is.*

- *Is TAI(k) distributable?*
  - *Political decision…*
  - *Introduce TI in its place?*

Distribution of Time

- Server/client responsibilities
  - **Time servers and OS system clocks** normally use time stamps encoded in a binary time-scale (i.e. not UTC or TAI)
    - Should represent RCT (but often do not)
    - Encapsulate this time-scale in a library (e.g. GPS)
  - **Client programs** interpret the time stamps into humanly accessible time-scales as configured by the system or application (TAI, UTC, EST, PDT, etc.)
    - Responsibility delayed to application code
    - Time service and OS code is NOT responsible for application code
    - Use whatever time-scale is appropriate
      - Documentation, standards, education!!!

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Distribution of Time

- UTC is currently the referential time-scale
  - Would a uniform time-scale be a better referential time-scale?
  - UTC has global acceptance as the reference for civil time

- Possible Hierarchy of Time-Scales:
  - TAI(BIPM) (not distributable)
    - Binary (represents RCT, time distribution, time stamps)
      - TI (predictable; for global scheduling, coordination of time, etc.)
      - UTC (Approximates UT1; basis of civil time)
        - » Time zones (EST, PDT, etc.)

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