Mean Solar Time, UT1, UTC, and Leap Seconds

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Time Scales

- Mean Solar Time
- Universal Time (UT1)
- Ephemeris Time
- International Atomic Time
- Coordinated Universal Time (UTC)
- Dynamical Time Scales
- Special Time Scales, *e.g.* internal GNSS Times
Coordinated Universal Time

- Broadcast time services
- UT1 and TAI
- Frequency offsets unacceptable
- 1972 definition by CCIR
- UTC based on TAI, <0.9 s from UT1
- DUT1
- BIH
- BIPM
- IERS
How well has UT kept up with GMT?

- Expected discrepancy: \( \sim \frac{\text{TT-UT}}{365\frac{1}{4}} \)
  - Right ascension of Newcomb’s mean sun related to Ephemeris Time (ET)

- Guinot’s (2011) Conjecture*
  - Decisions taken until now preserve UT1 as a representation of mean solar time at Greenwich “with a departure which may reach one or two seconds…”
    - Imprecise solar-transits relative to stars: \( \sim 0.1^s \)
    - Algorithm changes to International Bureau of Time (BIH) “mean observatory”: 10’ s of ms
    - Non-uniformity from polar motion: \( \sim 30 \) ms at Greenwich
    - Plate tectonics: centimeters (\( \mu s \)) per annum.
    - BIH perturbed longitude origin w/ terrestrial system changes...

Simulated Transit Times

- Simulated Transits (adjusted)
- $0.002738 \times \Delta T$

Graph showing the change in simulated transit times from Jan-1972 to Jan-2012.
“Modern” Mean Sun

\[ \Delta = 0.0286s - 0.5569T \]

UTC, Newcomb, Simon et al. (1994)
Redefinition of UTC 2000 - 2012

- ITU WP 7A Proposal
- Surveys, Discussions, Studies
  - Surveys favor the status quo
  - Lack of cost estimates
  - No consensus
- Opposing votes in ITU-R
  - Working Party 7A
  - Study Group 7
- Forwarded to Radiocommunications Assembly in 2012
Status of Redefinition of UTC

- Radio Communications Assembly Jan 2012
  - 190 countries could vote
  - ISO resolution concerning changing the name
  - Equal division of For, Against, Undecided
  - Delay Decision until 2015
- Call for a Study
  - continuous reference time-scale
  - other technical options
  - broader implications
- Russian Federation Contribution to SG7 recommending studies
Study Group 7 Considerations

• Are time transmissions only for telecommunications?
• Question not limited to technical and regulatory issues
  • Societal implications of modification of civil time scale
  • Organizational issues
  • Use of other technical options
    • leap minute?
    • time scale with fixed offset from TAI?
• Timetable required for bringing new time scale into use
Continuous Reference Time-Scale

- Is UTC *discontinuous*?
  - Definition of continuous?
    - parts in immediate connection
      - contiguous
    - uninterrupted in sequence
    - definition does not prescribe means of labeling
- What are the requirements for:
  - UTC?
  - Continuous Reference Time-Scale?
Impact of Change on Space Surveillance

- UTC would differ from UT1 without limit
  - UT1 needed for
    - Earth rotation
    - pointing of telescopes and antennae
- Real-time access to UT1 values needed
- UTC would have two different operational definitions
  - Software must change accordingly
- Care must be taken concerning the relationships between the different time scales
Some Options

- Retain *status-quo* UTC as is
- Redefine UTC:
  - Cease leap seconds
    - Proposed but not adopted in 2012
  - Cease leap seconds but also change name
  - Replace leap seconds with leap minutes
- Recognize alternative adjustment methods
  - Computer clock slewing before leap second
- Officially supplement UTC with another atomic scale:
  - TAI?
  - GNSS time?
  - Other?
Issues Concerning the Recommendation to Redefine UTC

• Significance with respect to Radiocommunications
  • Technical, legal, and public issues
  • Continuous time scale
• Involvement of International Standards and Scientific Organizations
  • ITU-R non consensus
  • IAU, IERS, URSI, AAS, ISO
• Terminology
  • Change definition -> change name
Issues Concerning the Recommendation to Redefine UTC

• Alternative Time Scales
  • GPS time already in use
  • TAI or equivalent, as a supplementary time scale

• User Preferences
  • Surveys favor status quo
  • Only “minor anomalies” with leap seconds reported
  • No substantial documentation supporting redefinition

• Software and Hardware Modifications
  • GNSS
  • Consult computer scientists and software developers
Issues Concerning the Recommendation to Redefine UTC

• Distribution of UT1
  • Availability and distribution of UT1 by computer network

• Legal Considerations
  • Status of UTC as official time in countries
  • Mean Solar Time as official time in countries

• Re-education
  • Revision of literature and textbooks
    • Change of knowledge base affects large number of users otherwise unaffected
    • Potentially confusing to non-experts
Issues Concerning the Recommendation to Redefine UTC

• Celestial Navigation and Almanacs
  • Changes in almanacs and explanations of use
  • Problem of navigation in an emergency
• Rate of Earth Rotation
  • Long and short term trends in Earth-rotation rate
• Long-Term Societal Effects
  • Long term adjustment procedure?
Personal Recommendation

- Recognize current practice
  - Retain UTC as is
  - Officially recognize a distinct uniform atomic time scale for those who need such a time scale
    - Real-time TAI(k)
    - GNSS-based time scale
    - Some other offset from TAI
  - Other options for method of introducing leap second in time scales
Personal Recommendation

Option with no cost increases or organization problems
- CIPM oversight of time scales, TAI, UTC, GNSS
- ITU distribution of UTC
- GNSS distribution of GNSS time scales
Basically recognizing current practice
What’s Next?

• Studies per WRC resolution
• Studies should consider
  • user requirements
  • options
    • pros and cons of each
• International Colloquium on “Requirements for UTC and Civil Timekeeping on Earth”
  Broader implications considered
  May 29-31, 2013, Charlottesville, Virginia
• Educate all nations concerning the issues
• Decision in 2015